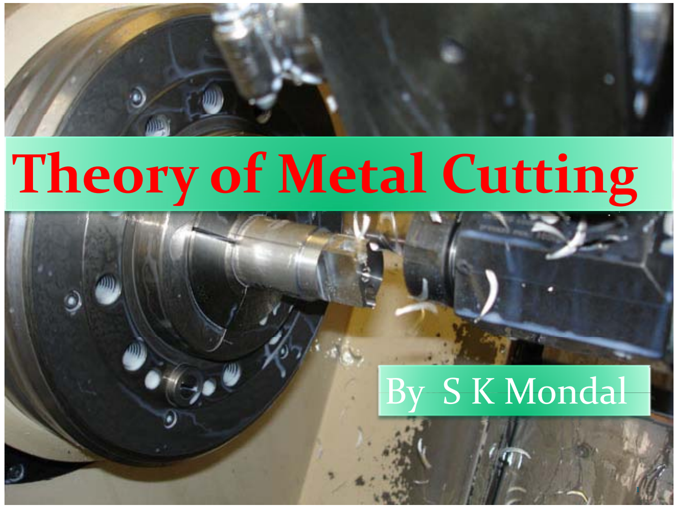
Metal Cutting, Metal Forming & Metrology

Questions & Answers-For 2019 (All Questions are in Sequence)

IES-1992-2018 (27 Yrs.), GATE-1992-2018 (27 Yrs.), GATE (PI)-2000-2018 (19 Yrs.), IAS-1994-2011 (18 Yrs.), some PSUs questions and conventional questions IES, IAS, IFS are added.

For-2019 (IES, GATE & PSUs)



Manufacturing Vs Production

- Manufacturing is a process of converting raw material in to finished product by using various processes, machines and energy, it is a narrow term.
- Production is a process of converting inputs in to outputs it is a broader term.

  Eg. 'crude oil production' not 'crude oil manufacturing', 'movie production' not 'movie manufacturing'
- Manufacturing and production are often used interchangeably.

Machine tool

A machine tool is a non-portable power operated and reasonably valued device or system of device in which energy is expended to produce jobs of desired size, shape and surface finish by removing excess material from the preformed blanks in the form of chips with the help of cutting tools moved past the work surface.

Why even a battery operated pencil sharpener cannot be accepted as a machine tool?

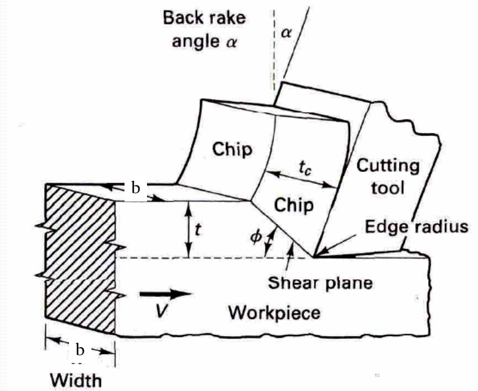
Ans. In spite of having all other major features of machine tools, the sharpener is of low value.

IAS 2009 main

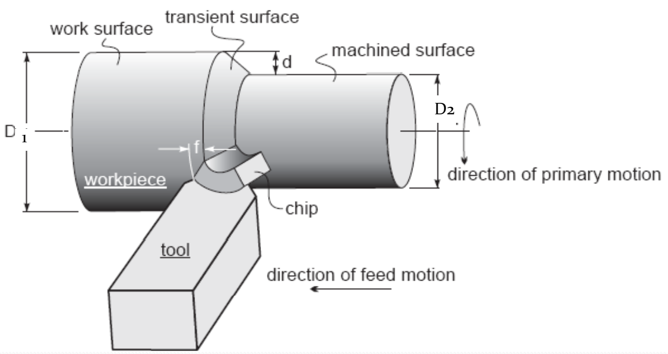
Name four independent variables and three dependent variables in metal cutting. [5 marks]

Independent Variables	Dependent Variables
•Starting materials (tool/work) •Tool geometry •Cutting Velocity •Lubrication • Feed & Depth of cut	•Force or power requirements •Maximum temperature in cutting •Surface finish

Orthogonal Machining



Speed, feed, and depth of cut



Cutting speed, feed, and depth of cut for a turning operation

IES-2013

Carbide tool is used to machine a 30 mm diameter steel shaft at a spindle speed of 1000 revolutions per minute. The cutting speed of the above turning operation is:

(*a*) 1000 rpm

(*b*) 1570 m/min

(*c*) 94.2 m/min

(*d*) 47.1 m/min

IES-2001

For cutting of brass with single-point cutting tool on a lathe, tool should have

(a) Negative rake angle

(b) Positive rake angle

(c) Zero rake angle

(d) Zero side relief angle

IES-1995

Single point thread cutting tool should ideally have:

a) Zero rake

b) Positive rake

c) Negative rake

d) Normal rake

GATE-1995; 2008

Cutting power consumption in turning can be significantly reduced by

(a) Increasing rake angle of the tool

(b) Increasing the cutting angles of the tool

(c) Widening the nose radius of the tool

(d) Increasing the clearance angle

IES-1993

Assertion (A): For a negative rake tool, the specific cutting pressure is smaller than for a positive rake tool under otherwise identical conditions.

Reason (R): The shear strain undergone by the chip in the case of negative rake tool is larger.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES – 2005

Assertion (A): Carbide tips are generally given negative rake angle.

Reason (R): Carbide tips are made from very hard materials.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES-2015

Statement (I) : The ceramic tools used in machining of material have highly brittle tool tips.

Statement (II) : Ceramic tools can be used on hard-to machine work material.

(a) Both statement (I) and (II) are individually true and statement (II) is the correct explanation of statement (I)

(b) Both statement (I) and statement(II) are individually true but statement(II) is **not** the correct explanation of statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but statement (II) is true

IES – 2002

Assertion (A): Negative rake is usually provided on carbide tipped tools.

Reason (R): Carbide tools are weaker in compression.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES 2011

Which one of the following statement is NOT correct with reference to the purposes and effects of rake angle of a cutting tool?

(a) To guide the chip flow direction

(b) To reduce the friction between the tool flanks and the machined surface

(c) To add keenness or sharpness to the cutting edges.

(d) To provide better thermal efficiency.

GATE – 2008 (PI)

Brittle materials are machined with tools having zero or negative rake angle because it

(a) results in lower cutting force

(b) improves surface finish

(c) provides adequate strength to cutting tool

(d) results in more accurate dimensions

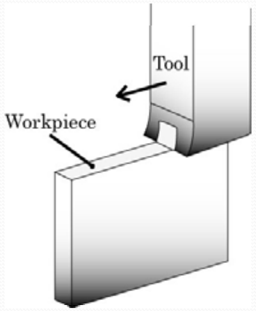
For IES Only

IES 2007 Conventional

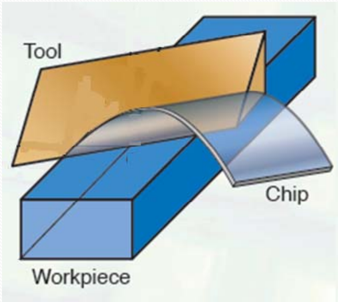
Cast iron with impurities of carbide requires a particular rake angle for efficient cutting with single point tools, what is the value of this rake angle, give reasons for your answer. [2 marks]

Answer: Free carbides in castings reduce their machinability and cause tool chipping or fracture, necessitating tools with high toughness. Zero rake tool is perfect for this purpose.

Types of Machining



Orthogonal Cutting



Oblique Cutting

19

IAS – 1994

Consider the following characteristics

1. The cutting edge is normal to the cutting velocity.
2. The cutting forces occur in two directions only.
3. The cutting edge is wider than the depth of cut.

The characteristics applicable to orthogonal cutting would include

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

20

IES - 2014

Which one of the following statements is correct about an oblique cutting?

(a) Direction of chip flow velocity is normal to the cutting edge of the tool

(b) Only two components of cutting forces act on the tool

(c) cutting edge of the tool is inclined at an acute angle to the direction of tool feed

(d) Cutting edge clears the width of the workpiece

21

IES - 2012

During orthogonal cutting, an increase in cutting speed causes

(a) An increase in longitudinal cutting force

(b) An increase in radial cutting force

(c) An increase in tangential cutting force

(d) Cutting forces to remain unaffected

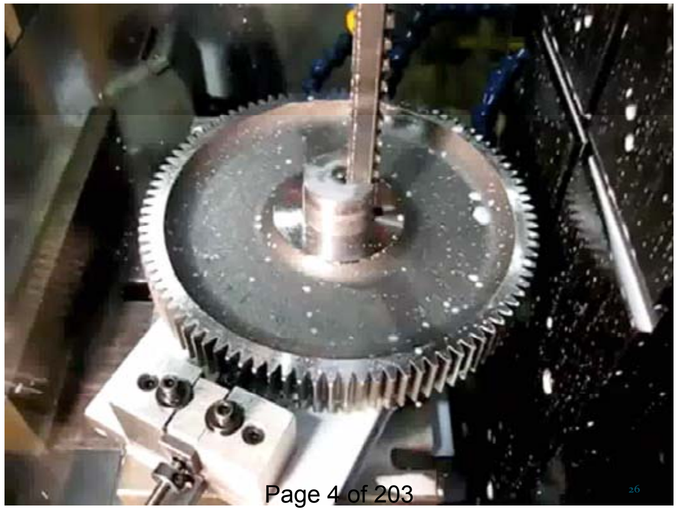
22

Chip formation of a drill

23

24

25



26

IES-2006

Which of the following is a single point cutting tool?

(a) Hacksaw blade

(b) Milling cutter

(c) Grinding wheel

(d) Parting tool

27

GATE-2017(PI)

Turning, drilling, boring and milling are commonly used machining operations. Among these, the operation(s) performed by a single point cutting tool is (are)

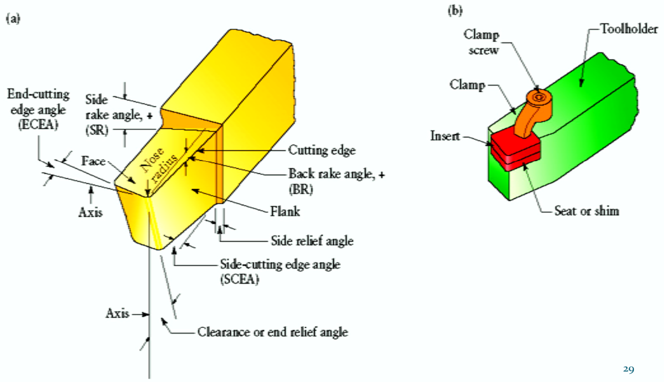
(a) turning

(b) drilling and milling only

(c) turning and boring only

(d) boring only

A Single Point Turning Tool



IES - 2012

Statement (I): Negative rake angles are preferred on rigid set-ups for interrupted cutting and difficult-to machine materials.

Statement (II):Negative rake angle directs the chips on to the machined surface

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

IES-2003

The angle of inclination of the rake face with respect to the tool base measured in a plane perpendicular to the base and parallel to the width of the tool is called

(a) Back rake angle

(b) Side rake angle

(c) Side cutting edge angle

(d) End cutting edge angle

IES-2015

The purpose of providing side rake angle in the cutting tool is

(a) avoid work from rubbing against tool

(b) Control chip flow

(c) Strengthen tool edge

(d) Break chips

GATE(PI)-1990

The diameter and rotational speed of a job are 100 mm and 500 rpm respectively. The high spot (Chatter marks) are found at a spacing of 30 deg on the job surface. The chatter frequency is

(a) 5 Hz (b) 12 Hz (c) 100 Hz (d) 500 Hz

IAS – 1996

The tool life increases with the

(a) Increase in side cutting edge angle

(b) Decrease in side rake angle

(c) Decrease in nose radius

(d) Decrease in back rake angle

IAS – 1995

Thrust force will increase with the increase in

(a) Side cutting edge angle

(b) Tool nose radius

(c) Rake angle

(d) End cutting edge angle.

IES 2010

Consider the following statements:

In an orthogonal, single-point metal cutting, as the side-cutting edge angle is increased,

1. The tangential force increases.
2. The longitudinal force drops.
3. The radial force increases.

Which of these statements are correct?

(a) 1 and 3 only (b) 1 and 2 only

(c) 2 and 3 only (d) 1, 2 and 3

IES-1995

The angle between the face and the flank of the single point cutting tool is known as

a) Rake angle
b) Clearance angle
c) Lip angle
d) Point angle.

IES-2006

Assertion (A): For drilling cast iron, the tool is provided with a point angle smaller than that required for a ductile material.

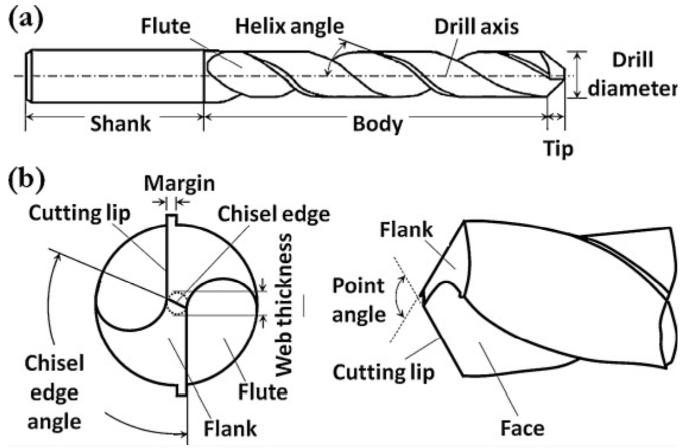
Reason (R): Smaller point angle results in lower rake angle.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is not the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true



Some Formulae for Drilling

$$Cone\ height\ (h) = \frac{D}{2\tan\beta}$$

$$Uncut\ chip\ thickness\ (t) = \frac{f}{2}\sin\beta$$

$$Width\ of\ cut\ (b) = \frac{D}{2\sin\beta}$$

$$Orthogonal\ rake\ angle\ (\alpha) = \tan^{-1}\left[\frac{(2r/D)\tan\psi}{\sin\beta}\right]$$

IES-2002

Consider the following statements:

The strength of a single point cutting tool depends upon

1. Rake angle
2. Clearance angle
3. Lip angle

Which of these statements are correct?

(a) 1 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1, 2 and 3

Nose radius

- It is curvature of the tool tip.
- It strengthen the tool nose by reducing stress concentration.
- It increases tool life.
- It provide better surface finish.
- But too large a nose radius will induce chatter.
- If nose radius increased cutting force and cutting power increased.

IES - 2012

Tool life increase with increase in
(a) Cutting speed
(b) Nose radius
(c) Feed
(d) Depth of cut

IES-2009

Consider the following statements with respect to the effects of a large nose radius on the tool:

1. It deteriorates surface finish.
2. It increases the possibility of chatter.
3. It improves tool life.

Which of the above statements is/are correct?

(a) 2 only (b) 3 only
(c) 2 and 3 only (d) 1, 2 and 3

IES-1995

Consider the following statements about nose radius

1. It improves tool life
2. It reduces the cutting force
3. It improves the surface finish.

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

IES-1994

Tool geometry of a single point cutting tool is specified by the following elements:

1. Back rake angle
2. Side rake angle
3. End cutting edge angle
4. Side cutting edge angle
5. Side relief angle
6. End relief angle
7. Nose radius

The correct sequence of these tool elements used for correctly specifying the tool geometry is

(a) 1, 2, 3, 6, 5, 4, 7 (b) 1, 2, 6, 5, 3, 4, 7
(c) 1, 2, 5, 6, 3, 4, 7 (d) 1, 2, 6, 3, 5, 4, 7

46

IES-2009

The following tool signature is specified for a single-point cutting tool in American system:

10, 12, 8, 6, 15, 20, 3

What does the angle 12 represent?

(a) Side cutting-edge angle
(b) Side rake angle
(c) Back rake angle
(d) Side clearance angle

47

IES-1993

In ASA System, if the tool nomenclature is 8-6-5-5-10-15-2-mm, then the side rake angle will be

(a) 5° (b) 6° (c) 8° (d) 10°

48

ISRO-2011

A cutting tool having tool signature as 10, 9, 6, 6, 8, 8, 2 will have side rake angle

(a) 10° (b) 9° (c) 8° (d) 2°

49

IES-2018

Tool signature is

(a) a numerical method of identification of the tool
(b) the plan of the tool
(c) the complete specification of the tool
(d) associated with the tool manufacturer

50

GATE-2008

In a single point turning tool, the side rake angle and orthogonal rake angle are equal. Φ is the principal cutting edge angle and its range is $0^o \le \phi \le 90^o$ **The chip flows in the orthogonal plane. The value of Φ is closest to**

(a) 0^0 (b) 45^0
(c) 60^0 (d) 90^0

51

GATE-2001

During orthogonal cutting of mild steel with a 10° rake angle tool, the chip thickness ratio was obtained as 0.4. The shear angle (in degrees) evaluated from this data is

(a) 6.53 (b) 20.22
(c) 22.94 (d) 50.00

52

GATE 2011

A single – point cutting tool with 12° rake angle is used to machine a steel work – piece. The depth of cut, i.e. uncut thickness is 0.81 mm. The chip thickness under orthogonal machining condition is 1.8 mm. The shear angle is approximately

(a) 22°
(b) 26°
(c) 56°
(d) 76°

53

GATE-2018

Following data correspond to an orthogonal Turning of a 100 mm diameter rod on a lathe. Rake angle: +15°; Uncut chip thickness 0.5 mm, nominal chip thickness after the cut 1.25 mm. The shear angle (in degrees) for this process is ________(correct to two decimal places).

54

GATE-2017

In an orthogonal machining with a tool of 9^o orthogonal rake angle, the uncut chip thickness is 0.2 mm. The chip thickness fluctuates between 0.25 mm and 0.4 mm. The ratio of the maximum shear angle to the minimum shear angle during machining is ___________

55

IES-1994

The following parameters determine the model of continuous chip formation:

1. True feed
2. Cutting velocity
3. Chip thickness
4. Rake angle of the cutting tool.

The parameters which govern the value of shear angle would include

(a) 1,2 and 3 (b) 1,3 and 4
(c) 1,2 and 4 (d) 2,3 and 4

56

IES-2014 Conventional

A bar of 70 mm diameter is being cut orthogonally and is reduced to 68 mm by a cutting tool. In case mean length of the chip is 68.9 mm, find the cutting ratio. Determine shear angle also if the rake angle is 10^o

[10 Marks]

Hint: length of uncut chip = πD

57

GATE-2014

During pure orthogonal turning operation of a hollow cylindrical pipe, it is found that the thickness of the chip produced is 0.5 mm. The feed given to the zero degree rake angle tool is 0.2 mm/rev. The shear strain produced during the operation is ....

58

IES - 2004

In a machining operation chip thickness ratio is 0.3 and the rake angle of the tool is 10°. What is the value of the shear strain?

(a) 0.31 (b) 0.13
(c) 3.00 (d) 3.34

59

IAS-2015 Main

In an orthogonal cutting operation, the tool has a rake angle = 10^o. The chip thickness before the cut = 0.5 mm and the cut yields a deformed chip thickness = 1.125 mm.

Calculate

(i) shear plane angle,

(ii) shear strain for the operation.

Derive the formulae that are to be used while finding out the shear plane angle and shear strain.

[20-Marks]

IES - 2009

Minimum shear strain in orthogonal turning with a cutting tool of zero rake angle is

(a) 0.0
(b) 0.5
(c) 1.0
(d) 2.0

61

GATE (PI)-1990

A single point cutting tool with 12^o rake angle is used for orthogonal machining of a ductile material. The shear plane angle for the theoretically minimum possible shear strain to occur

(a) 51 (b) 45
(c) 30 (d) None of these

62

IES-2016

During the formation of chips in machining with a cutting tool, which one of the following relations holds good?

$(a)\ \frac{V}{\cos(\phi-\alpha)}=\frac{V_s}{\cos\alpha}=\frac{V_c}{\sin\alpha}$ $(b)\ \frac{V}{\sin(\phi-\alpha)}=\frac{V_s}{\cos\alpha}=\frac{V_c}{\cos\alpha}$

$(c)\ \frac{V}{\cos\alpha}=\frac{V_c}{\sin\alpha}=\frac{V_s}{\sin(\phi-\alpha)}$ $(d)\ V\cos\alpha=V_c\sin\alpha=V_s\cos(\alpha-\phi)$

where V is the cutting speed, Vc is the velocity of the chip, Vs is the velocity at which shearing takes place along the shear plane, ϕ is the shear angle and α is the rake angle.

63

GATE -2012

Details pertaining to an orthogonal metal cutting process are given below.

Chip thickness ratio	0.4
Undeformed thickness	0.6 mm
Rake angle	+10°
Cutting speed	2.5 m/s

Mean thickness of primary shear zone 25 microns

The shear strain rate in s^{-1} during the process is

(a) 0.1781×10^5 (b) 0.7754×10^5

(c) 1.0104×10^5 (d) 4.397×10^5

64

IES-2004

Consider the following statements with respect to the relief angle of cutting tool:

1. This affects the direction of chip flow

2. This reduces excessive friction between the tool and work piece

3. This affects tool life

4. This allows better access of coolant to the tool work piece interface

Which of the statements given above are correct?

(a) 1 and 2 (b) 2 and 3

(c) 2 and 4 (d) 3 and 4

65

IES-2006

Consider the following statements:

1. A large rake angle means lower strength of the cutting edge.

2. Cutting torque decreases with rake angle.

Which of the statements given above is/are correct?

(a) Only 1 (b) Only 2

(c) Both 1 and 2 (d) Neither 1 nor 2

66

IES-2004

Match. List I with List II and select the correct answer using the codes given below the Lists:

	List I		List II
A.	**Plan approach angle**	**1.**	**Tool face**
B.	**Rake angle**	**2.**	**Tool flank**
C.	**Clearance angle**	**3.**	**Tool face and flank**
D.	**Wedge angle**	**4.**	**Cutting edge**
		5.	**Tool nose**

	A	B	C	D		A	B	C	D
(a)	1	4	2	5	(b)	4	1	3	2
(c)	4	1	2	3	(d)	1	4	3	5

67

IES-2004, ISRO-2009

The rake angle of a cutting tool is 15°, shear angle 45° and cutting velocity 35 m/min. What is the velocity of chip along the tool face?

(a) 28.5 m/min (b) 27.3 m/min

(c) 25.3 m/min (d) 23.5 m/min

68

IES-2008

Consider the following statements:

In an orthogonal cutting the cutting ratio is found to be 0·75. The cutting speed is 60 m/min and depth of cut 2·4 mm. Which of the following are correct?

1. Chip velocity will be 45 m/min.
2. Chip velocity will be 80 m/min.
3. Chip thickness will be 1·8 mm.
4. Chip thickness will be 3·2 mm.

Select the correct answer using the code given below:

(a) 1 and 3 (b) 1 and 4

(c) 2 and 3 (d) 2 and 4

69

IES - 2014

In an orthogonal turning process, the chip thickness = 0.32 mm, feed = 0.2 mm/rev. then the cutting ratio will be

(a) 2.6

(b) 3.2

(c) 1.6

(d) 1.8

70

IES-2001

If α is the rake angle of the cutting tool, ϕ is the shear angle and V is the cutting velocity, then the velocity of chip sliding along the shear plane is given by

(a) $\frac{V\cos\alpha}{\cos(\phi-\alpha)}$ (b) $\frac{V\sin\phi}{\cos(\phi-\alpha)}$

(c) $\frac{V\cos\alpha}{\sin(\phi-\alpha)}$ (d) $\frac{V\sin\alpha}{\sin(\phi-\alpha)}$

71

IES-2003

An orthogonal cutting operation is being carried out under the following conditions: cutting speed = 2 m/s, depth of cut = 0.5 mm, chip thickness = 0.6 mm. Then the chip velocity is

(a) 2.0 m/s (b) 2.4 m/s

(c) 1.0 m/s (d) 1.66 m/s

72

IAS-2003

In orthogonal cutting, shear angle is the angle between

(a) Shear plane and the cutting velocity

(b) Shear plane and the rake plane

(c) Shear plane and the vertical direction

(d) Shear plane and the direction of elongation of crystals in the chip

IAS-2002

If V = cutting velocity, ϕ = shear angle, α = rake angle, the chip velocity is

(a) $\dfrac{V\sin\phi}{\cos(\phi-\alpha)}$ (b) $\dfrac{V\cos(\phi-\alpha)}{\sin\phi}$

(c) $\dfrac{V\cos\phi}{\sin(\phi-\alpha)}$ (d) $\dfrac{V\sin(\phi-\alpha)}{\cos\phi}$

IAS-2000

The chip thickness ratio r is given by

(a) $\dfrac{\cos\phi}{\sin(\phi-\alpha)}$ (b) $\dfrac{\sin(\phi-\alpha)}{\cos\phi}$

(c) $\dfrac{\cos(\phi-\alpha)}{\sin\alpha}$ (d) $\dfrac{\sin\phi}{\cos(\phi-\alpha)}$

IAS-1998

The cutting velocity in m/sec, for turning a work piece of diameter 100 mm at the spindle speed of 480 RPM is

(a) 1.26 (b) 2.51 (c) 48 (d) 151

IAS-1995

In an orthogonal cutting, the depth of cut is halved and the feed rate is double. If the chip thickness ratio is unaffected with the changed cutting conditions, the actual chip thickness will be

(a) Doubled (b) halved

(c) Quadrupled (d) Unchanged.

GATE – 2009 (PI) Common Data S-1

An orthogonal turning operation is carried out at 20 m/min cutting speed, using a cutting tool of rake angle 15°. The chip thickness is 0.4 mm and the uncut chip thickness is 0.2 mm.

The shear plane angle (in degrees) is

(a) 26.8 (b) 27.8 (c) 28.8 (d) 29.8

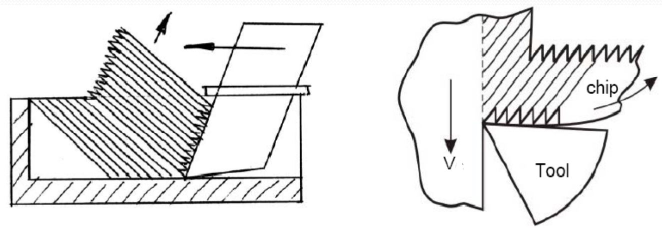
GATE – 2009 (PI) Common Data S-2

An orthogonal turning operation is carried out at 20 m/min cutting speed, using a cutting tool of rake angle 15°. The chip thickness is 0.4 mm and the uncut chip thickness is 0.2 mm.

The chip velocity (in m/min) is

(a) 8 (b) 10 (c) 12 (d) 14

Mechanism of chip formation in ductile material



(a) Shifting of the postcards by partial sliding against each other

(b) Chip formation by shear in lamella.

Mechanism of chip formation in brittle material

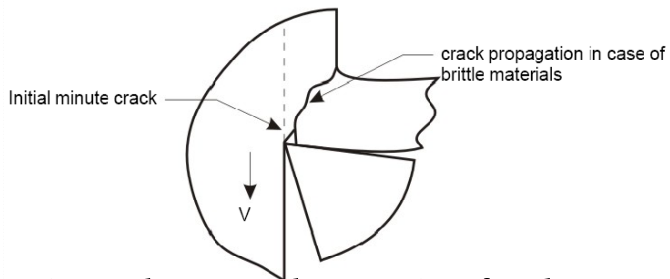


Fig. Development and propagation of crack causing chip separation.

GATE-1995

Plain milling of mild steel plate produces

(a) Irregular shaped discontinuous chips

(b) Regular shaped discontinuous chip

(c) Continuous chips without built up edge

(d) Joined chips

82

IES 2007

During machining, excess metal is removed in the form of chip as in the case of turning on a lathe. Which of the following are correct?

Continuous ribbon like chip is formed when turning

1. **At a higher cutting speed**
2. **At a lower cutting speed**
3. **A brittle material**
4. **A ductile material**

Select the correct answer using the code given below:

(a) 1 and 3 (b) 1 and 4

(c) 2 and 3 (d) 2 and 4

83

IES-2015

Coarse feed , low rake angle, low cutting speed and insufficient cooling help produce

(a) continuous chips in ductile materials

(b) discontinuous chips in ductile materials

(c) continuous chips with built-up edges in ductile materials

(d) discontinuous chips in brittle materials

84

IAS-1997

Consider the following machining conditions: BUE will form in

(a) Ductile material. (b) High cutting speed.

(c) Small rake angle. (d) Small uncut chip thickness.

85

GATE-2002

A built-up-edge is formed while machining

(a) Ductile materials at high speed

(b) Ductile materials at low speed

(c) Brittle materials at high speed

(d) Brittle materials at low speed

86

GATE-2009

Friction at the tool-chip interface can be reduced by

(a) decreasing the rake angle

(b) increasing the depth of cut

(c) Decreasing the cutting speed

(d) increasing the cutting speed

87

IES-1997

Assertion (A): For high speed turning of cast iron pistons, carbide tool bits are provided with chip breakers.

Reason (R): High speed turning may produce long, ribbon type continuous chips which must be broken into small lengths which otherwise would be difficult to handle and may prove hazardous.

(a) Both A and R are individually true and R is the correct explanation of A

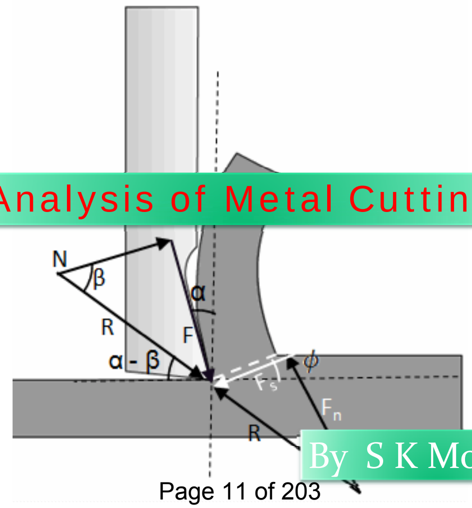
(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

88

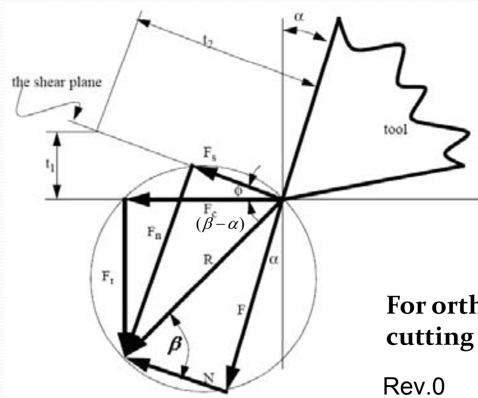
Analysis of Metal Cutting



By S K Mondal

89

Merchant Force Circle Diagram (MCD)



For orthogonal cutting only

90

ESE -2000 (Conventional)

The following data from the orthogonal cutting test is available. Rake angle = 10°, chip thickness ratio = 0.35, uncut chip thickness = 0.51 mm, width of cut = 3 mm, yield shear stress of work material = 285 N/mm², mean friction co-efficient on tool face = 0.65, Determine

(i) Cutting force (F_c)

(ii) Radial force

(iii) Normal force (N) on tool and

(iv) Shear force (F_s).

Limitations of use of MCD

1. MCD is valid only for orthogonal cutting.
2. By the ratio F/N, the MCD gives apparent (not actual) co-efficient of friction.

Special Case-I

- If α = 0

Special Case-II

- If α = 0 and μ = 1

GATE -2010 (PI) Linked S-1

In orthogonal turning of an engineering alloy, it has been observed that the friction force acting at the chip-tool interface is 402.5 N and the friction force is also perpendicular to the cutting velocity vector. The feed velocity is negligibly small with respect to the cutting velocity. The ratio of friction force to normal force associated with the chip-tool interface is 1. The uncut chip thickness is 0.2 mm and the chip thickness is 0.4 mm. The cutting velocity is 2 m/s.

The shear force (in N) acting along the primary shear plane is

(a) 180.0 (b) 240.0 (c) 360.5 (d) 402.5

GATE -2010 (PI) Linked S-2

In orthogonal turning of an engineering alloy, it has been observed that the friction force acting at the chip-tool interface is 402.5 N and the friction force is also perpendicular to the cutting velocity vector. The feed velocity is negligibly small with respect to the cutting velocity. The ratio of friction force to normal force associated with the chip-tool interface is 1. The uncut chip thickness is 0.2 mm and the chip thickness is 0.4 mm. The cutting velocity is 2 m/s.

Assume that the energy expended during machining is completely converted to heat. The rate of heat generation (in W) at the primary shear plane is

(a) 180.5 (b) 200.5 (c) 302.5 (d) 402.5

Linked Answer Questions GATE-2013 S-1

In orthogonal turning of a bar of 100 mm diameter with a feed of 0.25 mm/rev, depth of cut of 4 mm and cutting velocity of 90 m/min, it is observed that the main (tangential)cutting force is perpendicular to friction force acting at the chip-tool interface. The main (tangential) cutting force is 1500 N.

- The orthogonal rake angle of the cutting tool in degree is

(a) zero (b) 3.58 (c) 5 (d) 7.16

Linked Answer Questions GATE-2013 S-2

In orthogonal turning of a bar of 100 mm diameter with a feed of 0.25 mm/rev, depth of cut of 4 mm and cutting velocity of 90 m/min, it is observed that the main (tangential)cutting force is perpendicular to friction force acting at the chip-tool interface. The main (tangential) cutting force is 1500 N.

- The normal force acting at the chip-tool interface in N is

(a) 1000 (b) 1500 (c) 2000 (d) 2500

GATE-2015

A single point cutting tool with 0° rake angle is used in an orthogonal machining process. At a cutting speed of 180 m/min, the thrust force is 490 N. If the coefficient of friction between the tool and the chip is 0.7, then the power consumption(in kW) for the machining operation is _____

IES-2014 Conventional

Show schematically the Merchant's force circle in orthogonal cutting. Derive the equations for shear and frictional forces in terms of the material properties and cutting process parameters. State also the assumptions made while arriving at the final equations.

[15-Marks]

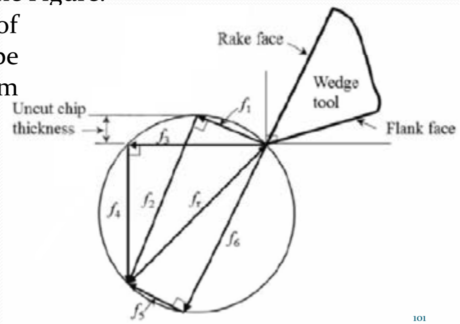
GATE-2017 (PI)

The Merchant circle diagram showing various forces associated with a cutting process using a wedge - shaped tool is given in the Figure.

The coefficient of friction can be estimated from the ratio

(a) $\frac{f_1}{f_2}$ (b) $\frac{f_3}{f_4}$

(c) $\frac{f_5}{f_6}$ (d) $\frac{f_6}{f_5}$



Merchant Theory or Analysis

Or Theory of Enrst and Merchant

Assumption

- The work material behaves like an ideal plastics.
- The theory involves minimum energy principle.
- τ_s and β are assumed to be constant, independent of ϕ
- It is based on single shear plane theory.
- The normal and shear stresses are distributed uniformly on the shear plane
- The deformation is in two dimensions only.

From Merchant Theory or Analysis

$$\phi = \frac{\pi}{4} + \frac{\alpha}{2} - \frac{\beta}{2}$$

- **Merchant theory gives higher shear plane angle means** smaller shear plane which means lower shear force
- **Result:** lower cutting forces, power, temperature, all of which mean easier machining

IAS – 1999

In an orthogonal cutting process, rake angle of the tool is 20° and friction angle is 25.5°. Using Merchant's shear angle relationship, the value of shear angle will be

(a) 39.5° (b) 42.25°

(c) 47.75° (d) 50.5°

GATE-1997

In a typical metal cutting operation, using a cutting tool of positive rake angle = 10°, it was observed that the shear angle was 20°. The friction angle is

(a) 45° (b) 30°

(c) 60° (d) 40°

ESE-2005 Conventional

Mild steel is being machined at a cutting speed of 200 m/min with a tool rake angle of 10. The width of cut and uncut thickness are 2 mm and 0.2 mm respectively. If the average value of co-efficient of friction between the tool and the chip is 0.5 and the shear stress of the work material is 400 N/mm², Determine

(i) shear angle and

(ii) Cutting and thrust component of the force.

GATE -2008 (PI) Linked S-1

In an orthogonal cutting experiment, an HSS tool having the following tool signature in the orthogonal reference system (ORS) has been used: 0-10-7-7-10-75-1. Given width of cut = 3.6 mm; shear strength of workpiece material = 460 N/mm²; depth of cut = 0.25 mm; coefficient of friction at tool-chip interface = 0.7.

Shear plane angle (in degree) for minimum cutting force is

(a) 20.5 (b) 24.5 (c) 28.5 (d) 32.5

GATE -2008 (PI) Linked S-2

In an orthogonal cutting experiment, an HSS tool having the following tool signature in the orthogonal reference system (ORS) has been used: 0-10-7-7-10-75-1. Given width of cut = 3.6 mm; shear strength of workpiece material = 460 N/mm²; depth of cut = 0.25 mm; coefficient of friction at tool-chip interface = 0.7.

Minimum power requirement (in kW) at a cutting speed of 150 m/min is

(a) 3.15 (b) 3.25 (c) 3.35 (d) 3.45

109

GATE-2014

Which pair of following statements is correct for orthogonal cutting using a single-point cutting tool?

P. Reduction in friction angle increases cutting force

Q. Reduction in friction angle decreases cutting force

R. Reduction in friction angle increases chip thickness

S. Reduction in friction angle decreases chip thickness

(*a*) P and R (*b*) P and S

(*c*) Q and R (*d*) Q and S

110

GATE-2014

Better surface finish is obtained with a large rake angle because

(*a*) the area of shear plane decreases resulting in the decrease in shear force and cutting force

(*b*) the tool becomes thinner and the cutting force is reduced

(*c*) less heat is accumulated in the cutting zone

(*d*) the friction between the chip and the tool is less

111

Modified Merchant Theory

$\tau_s = \tau_{so} + k\sigma_s$

Where, σ_s is the normal stress on shear plane $\left[\sigma_s = \frac{F_n}{A_s}\right]$

and then $2\phi + \beta - \alpha = \cot^{-1}(k)$

112

IES 2010

The relationship between the shear angle Φ, the friction angle β and cutting rake angle α is given as

(a) 2β + Φ − α = C

(b) 2Φ + β − α = C

(c) 2α + β − Φ = C

(d) Φ + 2β − α = C

113

IES-2005

Which one of the following is the correct expression for the Merchant's machinability constant?

(a) $2\phi + \gamma - \alpha$

(b) $2\phi - \gamma + \alpha$

(c) $2\phi - \gamma - \alpha$

(d) $\phi + \gamma - \alpha$

(Where ϕ = shear angle, γ = friction angle and α = rake angle)

114

Theory of Lee and Shaffer

- Based on slip line field theory.
- They applied the theory of plasticity for an ideal-rigid-plastic body.
- They also assumed that deformation occured on a thin-shear zone.

And derive

$$\phi = \frac{\pi}{4} + \alpha - \beta$$

115

IFS-2016

In a slab milling operation with straight teeth cutter, the cutter has 15 teeth with 10° rake angle and rotates at 200 rpm. The diameter of the cutter is 80 mm and table feed is 75 mm/min, the depth of cut is 5 mm, the width of slab is 50 mm and ultimate shear stress of work material is 420 N/mm². Assuming the coefficient of friction between chip and cutter to be 0.7 and using Lee and Shaffer relation, plot variation of resultant torque and cutter rotation, and estimate average power consumption.

116

Other Relations

- **By *Stabler***

$$\phi = \frac{\pi}{4} + \frac{\alpha}{2} - \beta$$

117

The force relations (VIMP)

$$F = F_c \sin\alpha + F_t \cos\alpha$$

$$N = F_c \cos\alpha - F_t \sin\alpha$$

$$F_n = F_c \sin\phi + F_t \cos\phi$$

$$F_s = F_c \cos\phi - F_t \sin\phi$$

and $\mu = \frac{F}{N} = \tan\beta$

118

IES-2003

In orthogonal cutting test, the cutting force = 900 N, the thrust force = 600 N and chip shear angle is 30°. Then the chip shear force is

(a) 1079.4 N (b) 969.6 N

(c) 479.4 N (d) 69.6 N

119

IES - 2014

In an orthogonal cutting operation shear angle = 11.31°, cutting force = 900 N and thrust force = 810 N. Then the shear force will be approximately (given sin 11.31° = 0.2)

(a) 650 N

(b) 720 N

(c) 620 N

(d) 680 N

120

IES-2000

In an orthogonal cutting test, the cutting force and thrust force were observed to be 1000N and 500 N respectively. If the rake angle of tool is zero, the coefficient of friction in chip-tool interface will be

(a) $\frac{1}{2}$ (b) 2 (c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

121

GATE-2016

In an orthogonal cutting process the tool used has rake angle of zero degree. The measured cutting force and thrust force are 500 N and 250 N, respectively. The coefficient of friction between the tool and the chip is

____

122

IES-2018

While turning a 60 mm diameter bar, it was observed that the tangential cutting force was 3000 N and the feed force was 1200 N. If the tool rake angle is 32°, then the coefficient of friction is nearly (may take sin32° = 0.53, cos32° = 0.85 and tan32° = 0.62)

(a) 1.37 (b) 1.46 (c) 1.57 (d) 1.68

123

GATE – 2007 (PI) Common Data-1

In an orthogonal machining test, the following observations were made

Cutting force	1200 N
Thrust force	500 N
Tool rake angle	zero
Cutting speed	1 m/s
Depth of cut	0.8 mm
Chip thickness	1.5 mm

Friction angle during machining will be

(a) 22.6° (b) 32.8° (c) 57.1° (d) 67.4°

124

GATE – 2007 (PI) Common Data-2

In an orthogonal machining test, the following observations were made

Cutting force	1200 N
Thrust force	500 N
Tool rake angle	zero
Cutting speed	1 m/s
Depth of cut	0.8 mm
Chip thickness	1.5 mm

Chip speed along the tool rake face will be

(a) 0.83 m/s (b) 0.53 m/s

(c) 1.2 m/s (d) 1.88 m/s

125

GATE – 2011 (PI) Linked S1

During orthogonal machining of a mild steel specimen with a cutting tool of zero rake angle, the following data is obtained:

Uncut chip thickness = 0.25 mm

Chip thickness = 0.75 mm

Width of cut = 2.5 mm

Normal force = 950 N

Thrust force = 475 N

The shear angle and shear force, respectively, are

(a) 71.565°, 150.21 N (b) 18.435°, 751.04 N

(c) 9.218°, 861.64 N (d) 23.157°, 686.66 N

126

GATE – 2011 (PI) Linked S2

During orthogonal machining of a mild steel specimen with a cutting tool of zero rake angle, the following data is obtained:

Uncut chip thickness = 0.25 mm

Chip thickness = 0.75 mm

Width of cut = 2.5 mm

Normal force = 950 N

Thrust force = 475 N

The ultimate shear stress (in N/mm²) of the work material is

(a) 235 (b) 139 (c) 564 (d) 380

127

IFS-2012

An orthogonal machining operation is being carried out under the following conditions :

depth of cut = 0.1 mm,

chip thickness = 0.2 mm,

width of cut = 5 mm,

rake angle = 10°

The force components along and normal to the direction of cutting velocity are 500 N and 200 N respectively. Determine

(i) The coefficient of friction between the tool and chip.

(ii) Ultimate shear stress of the workpiece material. [10]

128

GATE-2006 Common Data Questions(1)

In an orthogonal machining operation:

Uncut thickness = 0.5 mm

Cutting speed = 20 m/min Rake angle = 15°

Width of cut = 5 mm Chip thickness = 0.7 mm

Thrust force = 200 N Cutting force = 1200 N

Assume Merchant's theory.

The coefficient of friction at the tool-chip interface is

(a) 0.23 (b) 0.46

(c) 0.85 (d) 0.95

129

GATE-2006 Common Data Questions(2)

In an orthogonal machining operation:

Uncut thickness = 0.5 mm

Cutting speed = 20 m/min Rake angle = 15°

Width of cut = 5 mm Chip thickness = 0.7 mm

Thrust force = 200 N Cutting force = 1200 N

Assume Merchant's theory.

The percentage of total energy dissipated due to friction at the tool-chip interface is

(a) 30% (b) 42%

(c) 58% (d) 70%

130

GATE-2006 Common Data Questions(3)

In an orthogonal machining operation:

Uncut thickness = 0.5 mm

Cutting speed = 20 m/min Rake angle = 15°

Width of cut = 5 mm Chip thickness = 0.7 mm

Thrust force = 200 N Cutting force = 1200 N

Assume Merchant's theory.

The values of shear angle and shear strain, respectively, are

(a) 30.3° and 1.98 (b) 30.3° and 4.23

(c) 40.2° and 2.97 (d) 40.2° and 1.65

131

GATE-2018

An orthogonal cutting operations is being carried out in which uncut thickness is 0.010 mm, cutting speed is 130 m/min, rake angle is 15° and width of cut is 6 mm. It is observed that the chip thickness is 0.015 mm, the cutting force is 60 N and the thrust force is 25 N. The ratio of friction energy to total energy is_____________(correct to two decimal places)

132

- F_c or F_z or tangential component or primary cutting force acting in the direction of the cutting velocity, largest force and accounts for 99% of the power required by the process.
- F_x or axial component or feed force acting in the direction of the tool feed. This force is about 50% of F_c, but accounts for only a small percentage of the power required because feed rates are usually small compared to cutting speeds.
- F_y or radial force or thrust force in turning acting perpendicular to the machined surface. This force is about 50% of F_x i.e. 25% of F_c and contributes very little to power requirements because velocity in the radial direction is negligible.

133

IES-1995

The primary tool force used in calculating the total power consumption in machining is the

(a) Radial force (b) Tangential force

(c) Axial force (d) Frictional force.

134

IES-2001

Power consumption in metal cutting is mainly due to

(a) Tangential component of the force

(b) Longitudinal component of the force

(c) Normal component of the force

(d) Friction at the metal-tool interface

135

IES-1997

Consider the following forces acting on a finish turning tool:

1. Feed force
2. Thrust force
3. Cutting force.

The correct sequence of the decreasing order of the magnitudes of these forces is

(a) 1, 2, 3 (b) 2, 3, 1

(c) 3, 1, 2 (d) 3, 2, 1

136

IES-1999

The radial force in single-point tool during turning operation varies between

(a) 0.2 to 0.4 times the main cutting force

(b) 0.4 to 0.6 times the main cutting force

(c) 0.6 to 0.8 times the main cutting force

(d) 0.5 to 0.6 times the main cutting force

137

IFS-2015

Q. Why the knowledge of the thrust force in cutting is important ?

Answer: A knowledge of the thrust force in cutting is important because the tool holder, the work-holding devices, and the machine tool must be sufficiently stiff to support that force with nominal deflection.

138

Conversion Formula

We have to convert turning (3D) to Orthogonal Cutting (2D)

$$F_c = F_z$$

$$F_t = F_{xy} = \frac{F_x}{\sin\lambda} = \frac{F_y}{\cos\lambda} = \sqrt{F_x^2 + F_y^2}$$

139

Determination of Un-deformed chip thickness in Turning: (VIMP)

For single point cutting tool

$$t = f\sin\lambda$$

$$b = \frac{d}{\sin\lambda}$$

Where

t =Uncut chip thickness

f = feed

λ = 90 – C_s = approach angle

C_s = side cutting edge angle

$$l = \pi D$$

140

GATE-2014

A straight turning operation is carried out using a single point cutting tool on an AISI 1020 steel rod. The feed is 0.2 mm/rev and the depth of cut is 0.5 mm. The tool has a side cutting edge angle of 60°. The uncut chip thickness (in mm) is ....

141

ESE-2003- Conventional

During turning a carbon steel rod of 160 mm diameter by a carbide tool of geometry; 0, 0, 10, 8, 15, 75, 0 (mm) at speed of 400 rpm, feed of 0.32 mm/rev and 4.0 mm depth of cut, the following observation were made.

Tangential component of the cutting force, P_z = 1200 N

Axial component of the cutting force, P_x = 800 N

Chip thickness (after cut), a_2 = 0.8 mm.

For the above machining condition determine the values of

(i) Friction force, F and normal force, N acting at the chip tool interface.

(ii) Yield shears strength of the work material under this machining condition.

(iii) Cutting power consumption in kW.

142

GATE – 1995 -Conventional

While turning a C-15 steel rod of 160 mm diameter at 315 rpm, 2.5 mm depth of cut and feed of 0.16 mm/rev by a tool of geometry 0°, 10°, 8°, 9°,15°, 75°, 0(mm), the following observations were made.

Tangential component of the cutting force = 500 N

Axial component of the cutting force = 200 N

Chip thickness = 0.48 mm

Draw schematically the Merchant's circle diagram for the cutting force in the present case.

143

IAS-2003 Main Examination

During turning process with 7 - - 6 – 6 – 8 – 30 – 1 (mm) ASA tool the undeformed chip thickness of 2.0 mm and width of cut of 2.5 mm were used. The side rake angle of the tool was a chosen that the machining operation could be approximated to be orthogonal cutting. The tangential cutting force and thrust force were 1177 N and 560 N respectively. Calculate: [30 marks]

(i) The side rake angle

(ii) Co-efficient of friction at the rake face

(iii) The dynamic shear strength of the work material

144

Orthogonal Turning (λ = 90°)

$$F_c = F_z$$

$$F_t = \frac{F_x}{\sin\lambda} = \frac{F_x}{\sin 90} = F_x$$

$$t = f\sin\lambda = f\sin 90 = f$$

$$b = \frac{d}{\sin\lambda} = \frac{d}{\sin 90} = d$$

145

GATE-2007

In orthogonal turning of a low carbon steel bar of diameter 150 mm with uncoated carbide tool, the cutting velocity is 90 m/min. The feed is 0.24 mm/rev and the depth of cut is 2 mm. The chip thickness obtained is 0.48 mm. If the orthogonal rake angle is zero and the principal cutting edge angle is 90°, the shear angle is degree is

(a) 20.56 (b) 26.56

(c) 30.56 (d) 36.56

146

GATE-2015

An orthogonal turning operation is carried out under the following conditions: rake angle = 5°, spindle rotational speed = 400 rpm, axial feed = 0.4 m/min and radial depth of cut = 5 mm. The chip thickness, t_c is found to be 3 mm . The shear angle (in degrees) in this turning process is _____

147

GATE-2015

Orthogonal turning of mild steel tube with a tool rake angle of 10° is carried out at a feed of 0.14 mm/rev. If the thickness of chip produced is 0.28 mm. The values of shear angle and shear strain is

a) 28°20′ and 2.19

b) 22°20′ and 3.53

c) 24°20′ and 4.19

d) 37°20′ and 5.19

148

GATE-2016

For an orthogonal cutting operation, tool material is HSS, rake angle is 22° , chip thickness is 0.8 mm, speed is 48 m/min and feed is 0.4 mm/rev. The shear plane angle (in degree) is

149

GATE-2007

In orthogonal turning of low carbon steel pipe with principal cutting edge angle of 90°, the main cutting force is 1000 N and the feed force is 800 N. The shear angle is 25° and orthogonal rake angle is zero. Employing Merchant's theory, the ratio of friction force to normal force acting on the cutting tool is

(a) 1.56 (b) 1.25 (c) 0.80 (d) 0.64

150

GATE-2003 Common Data Questions(1)

A cylinder is turned on a lathe with orthogonal machining principle. Spindle rotates at 200 rpm. The axial feed rate is 0.25 mm per revolution. Depth of cut is 0.4 mm. The rake angle is 10°. In the analysis it is found that the shear angle is 27.75°

The thickness of the produced chip is

(a) 0.511 mm (b) 0.528 mm

(c) 0.818 mm (d) 0.846 mm

151

GATE-2003 Common Data Questions(2)

A cylinder is turned on a lathe with orthogonal machining principle. Spindle rotates at 200 rpm. The axial feed rate is 0.25 mm per revolution. Depth of cut is 0.4 mm. The rake angle is 10°. In the analysis it is found that the shear angle is 27.75°

In the above problem, the coefficient of friction at the chip tool interface obtained using Earnest and Merchant theory is

(a) 0.18 (b) 0.36

(c) 0.71 (d) 0.98

152

GATE-2008 Common Data Question (1)

Orthogonal turning is performed on a cylindrical work piece with shear strength of 250 MPa. The following conditions are used: cutting velocity is 180 m/min. feed is 0.20 mm/rev. depth of cut is 3 mm. chip thickness ratio = 0.5. The orthogonal rake angle is 7°. Apply Merchant's theory for analysis.

The shear plane angle (in degree) and the shear force respectively are

(a) 52: 320 N (b) 52: 400N

(c) 28: 400N (d) 28:320N

153

GATE-2008 Common Data Question (2)

Orthogonal turning is performed on a cylindrical work piece with shear strength of 250 MPa. The following conditions are used: cutting velocity is 180 m/min. feed is 0.20 mm/rev. depth of cut is 3 mm. chip thickness ratio = 0.5. The orthogonal rake angle is 7°. Apply Merchant's theory for analysis.

The cutting and Thrust forces, respectively, are

(a) 568N; 387N (b) 565N; 381N

(c) 440N; 342N (d) 480N; 356N

154

Metal Removal Rate (MRR)

Metal removal rate (MRR) = $A_c.V = b\,t\,V = fdV$

Where

A_c = cross-section area of uncut chip (mm^2)

V = cutting speed = $\pi DN,\ mm/\min$

155

IES - 2004

A medium carbon steel workpiece is turned on a lathe at 50 m/min. cutting speed 0.8 mm/rev feed and 1.5 mm depth of cut. What is the rate of metal removal?

(a) 1000 mm^3/min

(b) 60,000 mm^3/min

(c) 20,000 mm^3/min

(d) Can not be calculated with the given data

156

GATE-2013

A steel bar 200 mm in diameter is turned at a feed of 0.25 mm/rev with a depth of cut of 4 mm. The rotational speed of the workpiece is 160 rpm. The material removal rate in mm^3/s is

(a) 160 (b) 167.6 (c) 1600 (d) 1675.5

157

IES-2016

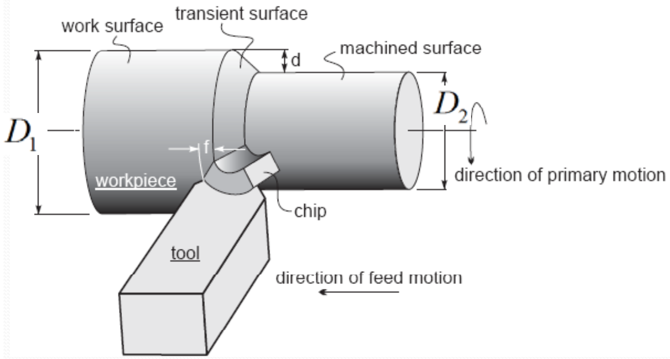
A 125 mm long, 10 mm diameter stainless steel rod is being turned to 9 mm diameter, 0.5 mm depth of cut. The spindle rotates at 360 rpm. With the tool traversing at an axial speed of 175 mm/min, the metal removal rate is nearly.

(a) 2200 mm^3/min (b) 2400 mm^3/min

(c) 2600 mm^3/min (d) 2800 mm^3/min

158

Turning



159

Power Consumed During Cutting

$$F_c.V$$

Where

F_c = cutting force (in N)

V = cutting speed = $\frac{\pi DN}{60}$, m/s

160

GATE-2018 (PI)

During orthogonal machining of a job at a cutting speed of 90 m/min with a tool of 10° rake angle, the cutting force and thrust force are 750 N and 390 N, respectively. Assume a shear angle of 35°. The power (in W) expended for shearing along the shear plane is ______

161

Specific Energy Consumption

$$e = \frac{Power(W)}{MRR\left(mm^3/s\right)} = \frac{F_c}{1000\,fd}$$

Sometimes it is also known as specific power consumption.

162

GATE(PI)-1991

Amount of energy consumption per unit volume of metal removal is maximum in

(a) Turning (b) Milling

(c) Reaming (d) Grinding

163

GATE-2007

In orthogonal turning of medium carbon steel. The specific machining energy is 2.0 J/mm³. The cutting velocity, feed and depth of cut are 120 m/min, 0.2 mm/rev and 2 mm respectively. The main cutting force in N is

(a) 40 (b) 80

(c) 400 (d) 800

164

GATE-2016 (PI)

A cylindrical bar of 100 mm diameter is orthogonally straight turned with cutting velocity, feed and depth of cut of 120 m/min, 0.25 mm/rev and 4 mm, respectively. The specific cutting energy of the work material is 1×10^3 J/m³. Neglect the contribution of feed force towards cutting power. The main or tangential cutting force (in N) is ________.

165

GATE-2013 (PI) Common Data Question

A disc of 200 mm outer and 80 mm inner diameter is faced of 0.1 mm/rev with a depth of cut of 1 mm. The facing operation is undertaken at a constant cutting speed of 90 m/min in a CNC lathe. The main (tangential) cutting force is 200 N.

Neglecting the contribution of the feed force towards cutting power, the specific cutting energy in J/mm³ is

(a) 0.2 (b) 2 (c) 200 (d) 2000

166

Specific Cutting Pressure

The cutting force, F_c, divided by the cross section area of the undeformed chip gives the nominal cutting stress or the specific cutting pressure, p_c

$$p_c = \frac{F_c}{bt} = \frac{F_c}{fd}$$

167

GATE-2014

The main cutting force acting on a tool during the turning (orthogonal cutting) operation of a metal is 400 N. The turning was performed using 2 mm depth of cut and 0.1 mm/rev feed rate. The specific cutting pressure is

(*a*) 1000

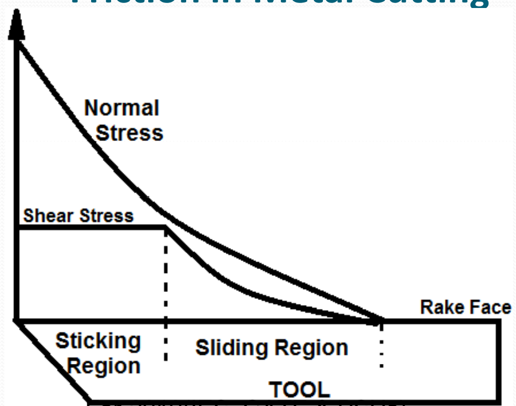
(*b*) 2000

(*c*) 3000

(*d*) 4000

168

Friction in Metal Cutting



169

GATE 1992

The effect of rake angle on the mean friction angle in machining can be explained by

(A) sliding (Coulomb) model of friction

(B) sticking and then sliding model of friction

(C) sticking friction

(D) Sliding and then sticking model of friction

170

GATE-1993

The effect of rake angle on the mean friction angle in machining can be explained by

(a) Sliding (coulomb) model of friction

(b) sticking and then siding model of friction

(c) Sticking friction

(d) sliding and then sticking model of friction

171

IES-2000

Assertion (A): In metal cutting, the normal laws of sliding friction are not applicable.

Reason (R): Very high temperature is produced at the tool-chip interface.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

172

IES-2004

Assertion (A): The ratio of uncut chip thickness to actual chip thickness is always less than one and is termed as cutting ratio in orthogonal cutting

Reason (R): The frictional force is very high due to the occurrence of sticking friction rather than sliding friction

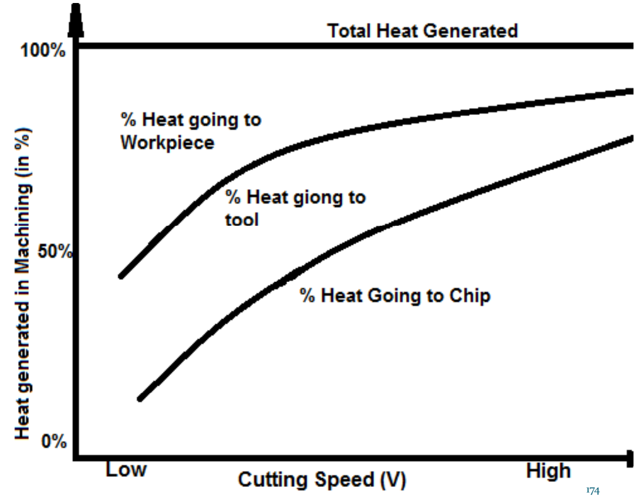
(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

173



174

IES-2002

In a machining process, the percentage of heat carried away by the chips is typically

(a) 5% (b) 25%

(c) 50% (d) 75%

175

IES-1998

In metal cutting operation, the approximate ratio of heat distributed among chip, tool and work, in that order is

(a) 80: 10: 10 (b) 33: 33: 33

(c) 20: 60: 10 (d) 10: 10: 80

176

IAS – 2003

As the cutting speed increases

(a) More heat is transmitted to the work piece and less heat is transmitted to the tool

(b) More heat is carried away by the chip and less heat is transmitted to the tool

(c) More heat is transmitted to both the chip and the tool

(d) More heat is transmitted to both the work piece and the tool

177

For IES Only

Mean Temperature in Turning

Mean temperature $\propto V^a f^b$

Tool Material	a	b
HSS	0.5	0.375
Carbide	0.2	0.125

178

Determination of cutting heat & temperature Experimentally

HEAT

- **Calorimetric method**

TEMPERATURE

- **Decolourising agent**
- **Tool-work thermocouple**
- **Moving thermocouple technique**
- **Embedded thermocouple technique**
- **Using compound tool**
- **Indirectly from Hardness and structural transformation**
- **Photo-cell technique**
- **Infra ray detection method**

179

IAS – 2003

The heat generated in metal cutting can conveniently be determined by

(a) Installing thermocouple on the job

(b) Installing thermocouple on the tool

(c) Calorimetric set-up

(d) Using radiation pyrometer

180

Dynamometer

- Dynamometers are used for measuring Cutting forces.
- For Orthogonal Cutting use 2D dynamometer
- For Oblique Cutting use 3D dynamometer

181

IES 2011

The instrument or device used to measure the cutting forces in machining is

(a) Tachometer

(b) Comparator

(c) Dynamometer

(d) Lactometer

182

IES-1993

A 'Dynamometer' is a device used for the measurement of

(a) Chip thickness ratio

(b) Forces during metal cutting

(c) Wear of the cutting tool

(d) Deflection of the cutting tool

183

IES-1996

Which of the following forces are measured directly by strain gauges or force dynamometers during metal cutting ?

1. Force exerted by the tool on the chip acting normally to the tool face.
2. Horizontal cutting force exerted by the tool on the work piece.
3. Frictional resistance of the tool against the chip flow acting along the tool face.
4. Vertical force which helps in holding the tool in position.

(a) 1 and 3 (b) 2 and 4

(c) 1 and 4 (d) 2 and 3

184

Types of Dynamometers

Strain gauge type

Or

piezoelectric type

Strain gauge type dynamometers are inexpensive but less accurate and consistent, whereas, the piezoelectric type are highly accurate, reliable and consistent but very expensive for high material cost and stringent construction.

185

Strain Gauge Dynamometers

The strain, ε induced by the force changes the electrical resistance, R, of the strain gauges which are firmly pasted on the surface of the tool-holding beam as

$$\frac{\Delta R}{R} = G\varepsilon$$

where, G = gauge factor (around 2.0 for conductive gauges)

The change in resistance of the gauges connected in a Wheatstone bridge produces voltage output ΔV, through a strain measuring bridge (SMB)

186

IES-1998

The gauge factor of a resistive pick-up of cutting force dynamometer is defined as the ratio of

(a) Applied strain to the resistance of the wire

(b) The proportional change in resistance to the applied strain

(c) The resistance to the applied strain

(d) Change in resistance to the applied strain

187

IES-2018

For a strain gauge (gauge factor = 2.1 and resistance = 50 Ω), subjected to a maximum strain of 0.001, the maximum change in resistance is

(a) 0.084 Ω (b) 0.105 Ω

(c) 0.135 Ω (d) 0.156 Ω

188

IAS-2001

Assertion (A): Piezoelectric transducers and preferred over strain gauge transducers in the dynamometers for measurement of three-dimensional cutting forces.

Reason (R): In electric transducers there is a significant leakage of signal from one axis to the other, such cross error is negligible in the case of piezoelectric transducers.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

189

For PSU & IES

In strain gauge dynamometers the use of how many active gauge makes the dynamometers more effective

(a) Four

(b) Three

(c) Two

(d) One

190

Tool Wear, Tool Life, Economics & Machinability

By S K Mondal

191

Tool Failure

Tool failure is two types

1. **Slow-death:** The gradual or progressive wearing away of rake face (crater wear) or flank (flank wear) of the cutting tool or both.

2. **Sudden-death:** Failures leading to premature end of the tool

The sudden-death type of tool failure is difficult to predict. Tool failure mechanisms include plastic deformation, brittle fracture, fatigue fracture or edge chipping. However it is difficult to predict which of these processes will dominate and when tool failure will occur.

192

IAS – 2009 Main

- Explain 'sudden-death mechanism' of tool failure. [4 – marks]

193

IES - 2014

The fatigue failure of a tool is due to

(a) abrasive friction, cutting fluid and chip breakage

(b) Variable thermal stresses, chip breakage and variable dimensions of cut

(c) Abrasive friction, chip breakage and variable dimensions of cut

(d) Chip breakage, variable thermal stresses and cutting fluid

194

Tool Wear

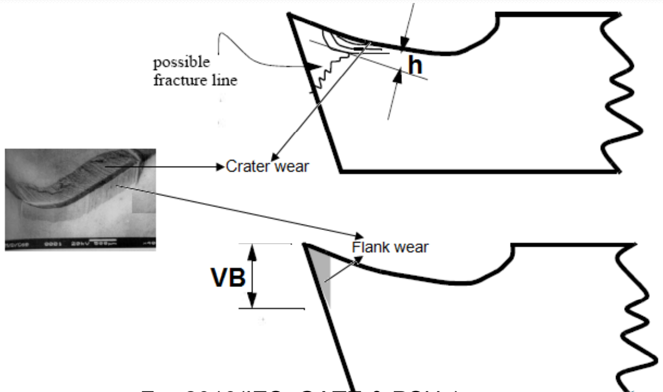
(a) Flank Wear

(b) Crater Wear

(c) Chipping off of the cutting edge

195

Tool Wear



196

IES 2010

Flank wear occurs on the

(a) Relief face of the tool

(b) Rake face

(c) Nose of the tool

(d) Cutting edge

197

IES – 2007, IES-2016

Flank wear occurs mainly on which of the following?

(a) Nose part and top face

(b) Cutting edge only

(c) Nose part, front relief face, and side relief face of the cutting tool

(d) Face of the cutting tool at a short distance from the cutting edge

198

IES – 1994

Assertion (A): Tool wear is expressed in terms of flank wear rather than crater wear.

Reason (R): Measurement of flank wear is simple and more accurate.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

Flank Wear: (Wear land)

Reason

- Abrasion by hard particles and inclusions in the work piece.
- Shearing off the micro welds between tool and work material.
- Abrasion by fragments of built-up-edge ploughing against the clearance face of the tool.
- At low speed flank wear predominates.
- If MRR increased flank wear increased.

GATE-2014

Cutting tool is much harder than the work-piece. Yet the tool wears out during the tool-work interaction, because

(*a*) extra hardness is imparted to the work-piece due to coolant used

(*b*) oxide layers on the work-piece surface impart extra hardness to it

(*c*) extra hardness is imparted to the work-piece due to severe rate of strain

(*d*) vibration is induced in the machine tool

Flank Wear: (Wear land)

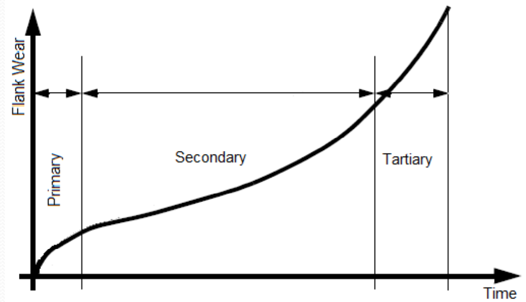
Effect

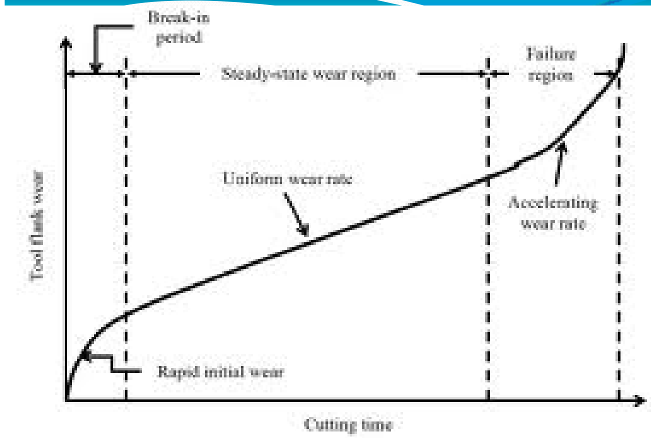
- Flank wear directly affect the component dimensions produced.
- Flank wear is usually the most common determinant of tool life.

Flank Wear: (Wear land)

Stages

- Flank Wear occurs in three stages of varying wear rates





Flank Wear: (Wear land)

Primary wear

The region where the sharp cutting edge is quickly broken down and a finite wear land is established.

Secondary wear

The region where the wear progresses at a uniform rate.

Flank Wear: (Wear land)

Tertiary wear

- The region where wear progresses at a gradually increasing rate.
- In the tertiary region the wear of the cutting tool has become sensitive to increased tool temperature due to high wear land.
- Re-grinding is recommended before they enter this region.

IES – 2004

Consider the following statements:

During the third stage of tool-wear, rapid deterioration of tool edge takes place because

1. Flank wear is only marginal
2. Flank wear is large
3. Temperature of the tool increases gradually
4. Temperature of the tool increases drastically

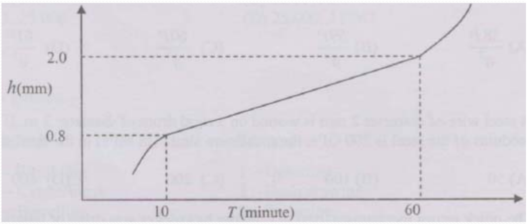
Which of the statements given above are correct?

(a) 1 and 3 (b) 2 and 4

(c) 1 and 4 (d) 2 and 3

GATE-2008 (PI)

During machining, the wear land (h) has been plotted against machining time (T) as given in the following figure.



For a critical wear land of 1.8 mm, the cutting tool life (in minute) is

(a) 52.00 (b) 51.67 (c) 51.50 (d) 50.00

208

IFS-2012

Explain the mechanism of flank wear of a cutting tool. Plot a flank wear rate curve and indicate the region of tool failure.

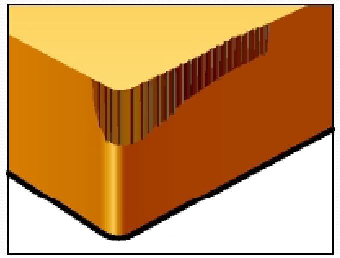
[10 Marks]

209

Tool life criteria ISO

(A certain width of flank wear (VB) is the most common criterion)

- Uniform wear: 0.3 mm averaged over all past
- Localized wear: 0.6 mm on any individual past



210

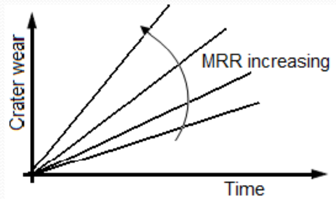
Crater wear

- More common in ductile materials which produce continuous chip.
- Crater wear occurs on the rake face.
- At very high speed crater wear predominates
- For crater wear temperature is main culprit and tool defuse into the chip material & tool temperature is maximum at some distance from the tool tip.

211

Crater wear Contd…..

- Crater depth exhibits linear increase with time.
- It increases with MRR.



- Crater wear has little or no influence on cutting forces, work piece tolerance or surface finish.

212

IES – 2002

Crater wear on tools always starts at some distance from the tool tip because at that point

(a) Cutting fluid does not penetrate
(b) Normal stress on rake face is maximum
(c) Temperature is maximum
(d) Tool strength is minimum

213

IAS – 2007

Why does crater wear start at some distance from the tool tip?

(a) Tool strength is minimum at that region
(b) Cutting fluid cannot penetrate that region
(c) Tool temperature is maximum in that region
(d) Stress on rake face is maximum at that region

214

IES – 2000

Crater wear starts at some distance from the tool tip because

(a) Cutting fluid cannot penetrate that region
(b) Stress on rake face is maximum at that region
(c) Tool strength is minimum at that region
(d) Tool temperature is maximum at that region

215

IES – 1995

Crater wear is predominant in

(a) Carbon steel tools
(b) Tungsten carbide tools
(c) High speed steel tools
(d) Ceramic tools

216

IES 2009 Conventional

Show crater wear and flank wear on a single point cutting tool. State the factors responsible for wear on a turning tool.

[2 –marks]

217

Wear Mechanism

1. Abrasion wear
2. Adhesion wear
3. Diffusion wear
4. Chemical or oxidation wear

218

IAS – 2002

Consider the following actions:

1. Mechanical abrasion 2. Diffusion
3. Plastic deformation 4. Oxidation

Which of the above are the causes of tool wear?

(a) 2 and 3 (b) 1 and 2
(c) 1, 2 and 4 (d) 1 and 3

219

IES – 1995

Match List I with List II and select the correct answer using the codes given below the lists:

List I (Wear type)	List II (Associated mechanism)
A. Abrasive wears	1. Galvanic action
B. Adhesive wears	2. Ploughing action
C. Electrolytic wear	3. Molecular transfer
D. Diffusion wears	4. Plastic deformation
	5. Metallic bond

Code:	A	B	C	D		A	B	C	D
(a)	2	5	1	3	(b)	5	2	1	3
(c)	2	1	3	4	(d)	5	2	3	4

220

IAS – 1999

The type of wear that occurs due to the cutting action of the particles in the cutting fluid is referred to as

(a) Attritions wear
(b) Diffusion wear
(c) Erosive wear
(d) Corrosive wear

221

Why chipping off or fine cracks developed at the cutting edge

- Tool material is too brittle
- Weak design of tool, such as high positive rake angle
- As a result of crack that is already in the tool
- Excessive static or shock loading of the tool.

222

IAS – 2003

Consider the following statements:

Chipping of a cutting tool is due to

1. Tool material being too brittle
2. Hot hardness of the tool material.
3. High positive rake angle of the tool.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2

223

Notch Wear

- Notch wear on the trailing edge is to a great extent an oxidation wear mechanism occurring where the cutting edge leaves the machined workpiece material in the feed direction.
- But abrasion and adhesion wear in a combined effect can contribute to the formation of one or several notches.

224

IES – 1996

Notch wear at the outside edge of the depth of cut is due to

(a) Abrasive action of the work hardened chip material
(b) Oxidation
(c) Slip-stick action of the chip
(d) Chipping.

225

List the important properties of cutting tool materials and explain why each is important.

- **Hardness at high temperatures** - this provides longer life of the cutting tool and allows higher cutting speeds.
- **Toughness** - to provide the structural strength needed to resist impacts and cutting forces
- **Wear resistance** - to prolong usage before replacement doesn't chemically react - another wear factor
- **Formable/manufacturable** - can be manufactured in a useful geometry

226

IES-2014 Conventional

- Describe the characteristics of tool materials.

[4-marks]

227

Why are ceramics normally provided as inserts for tools, and not as entire tools?

Ceramics are brittle materials and has low toughness cannot provide the structural strength required for a tool.

228

IES-2015

Which of the following statements are be correct for temperature rise in metal cutting operation?

1. It adversely affects the properties of tool material
2. It provides better accuracy during machining
3. It causes dimensional changes in the work-piece and affects the accuracy of machining
4. It can distort the accuracy of machine tool itself.

(a) 1 and 2 (b) 2 and 3

(c) 3 and 4 only (d) 1, 3 and 4

229

Tool Life Criteria

Tool life criteria can be defined as a predetermined numerical value of any type of tool deterioration which can be measured.

some of the ways

- Actual cutting time to failure.
- Volume of metal removed.
- Number of parts produced.
- Cutting speed for a given time
- Length of work machined.

230

IES – 1992

Tool life is generally specified by

(a) Number of pieces machined

(b) Volume of metal removed

(c) Actual cutting time

(d) Any of the above

231

IAS – 2012 Main

Define "tool life" and list down four methods for quantitative measurement of tool life.

[Marks -12]

232

Taylor's Tool Life Equation

Based on Flank Wear

Causes

- Sliding of the tool along the machined surface
- Temperature rise

$$VT^n = C$$

Where, V = cutting speed (m/min)

T = Time (min)

n = exponent depends on tool material

C = constant based on tool and work material and cutting condition.

233

Values of Exponent 'n'

n = 0.08 to 0.2 for HSS tool

= 0.1 to 0.15 for Cast Alloys

= 0.2 to 0.4 for carbide tool

[IAS-1999; IES-2006]

= 0.5 to 0.7 for ceramic tool

[NTPC-2003]

Reference: Kalpakjian

234

IES - 2012

In Taylor's tool life equation $VT^n = C$, the constants n and C depend upon

1. Work piece material
2. Tool material
3. Coolant

(a) 1, 2, and 3
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1 and 3 only

235

IES – 2008

In Taylor's tool life equation is VT^n = constant. What is the value of n for ceramic tools?

(a) 0.15 to 0.25 (b) 0.4 to 0.55
(c) 0.6 to 0.75 (d) 0.8 to 0.9

236

IES – 2006

Which of the following values of index n is associated with carbide tools when Taylor's tool life equation, $V.T^n$ = constant is applied?

(a) 0·1 to 0·15 (b) 0·2 to 0·4
(c) 0·45 to 0·6 (d) 0·65 to 0·9

237

IES – 1999

The approximately variation of the tool life exponent 'n' of cemented carbide tools is

(a) 0.03 to 0.08 (b) 0.08 to 0.20
(c) 0.20 to 0.48 (d) 0.48 to 0.70

238

IAS – 1998

Match List - I (Cutting tool material) with List - II (Typical value of tool life exponent 'n' in the Taylor's equation $V.T^n = C$) and select the correct answer using the codes given below the lists:

List – I	List – II
A. HSS	1. 0.18
B. Cast alloy	2. 0.12
C. Ceramic	3. 0.25
D. Sintered carbide	4. 0.5

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	4	3

239

IES-2016

In a machining test, a cutting speed of 100 m/min indicated the tool life as 16 min and a cutting speed of 200 m/min indicated the tool life as 4 min. The values of n and C are

(a) 0.5 and 200 (b) 0.25 and 200
(c) 0.5 and 400 (d) 0.25 and 400

240

GATE -2009 (PI)

In an orthogonal machining operation, the tool life obtained is 10 min at a cutting speed of 100 m/min, while at 75 m/min cutting speed, the tool life is 30 min. The value of index (n) in the Taylor's tool life equation

(a) 0.262 (b) 0.323 (c) 0.423 (d) 0.521

241

ISRO-2011

A 50 mm diameter steel rod was turned at 284 rpm and tool failure occurred in 10 minutes. The speed was changed to 232 rpm and the tool failed in 60 minutes. Assuming straight line relationship between cutting speed and tool life, the value of Taylorian Exponent is

(a) 0.21 (b) 0.13 (c) 0.11 (d) 0.23

242

GATE-2004, IES-2000

In a machining operation, doubling the cutting speed reduces the tool life to $\frac{1}{8}$th of the original value. The exponent n in Taylor's tool life equation $VT^n = C$, is

(a) $\frac{1}{8}$ (b) $\frac{1}{4}$ (c) $\frac{1}{3}$ (d) $\frac{1}{2}$

243

IES – 1999, ISRO-2013

In a single-point turning operation of steel with a cemented carbide tool, Taylor's tool life exponent is 0.25. If the cutting speed is halved, the tool life will increase by

(a) Two times (b) Four times

(c) Eight times (d) Sixteen times

244

GATE-2016

In a single point turning operation with cemented carbide tool and steel work piece, it is found that the Taylor's exponent is 0.25. If the cutting speed is reduced by 50% then the tool life changes by ______ times.

245

IAS – 1995

In a single point turning operation with a cemented carbide and steel combination having a Taylor exponent of 0.25, if the cutting speed is halved, then the tool life will become

(a) Half

(b) Two times

(c) Eight times

(d) Sixteen times

246

GATE-2015

Under certain cutting conditions, doubling the cutting speed reduces the tool life to 1/16th of the original. Taylor's tool life index (n) for this tool-workpiece combination will be _______

247

IAS – 2002

Using the Taylor equation VT^n = c, calculate the percentage increase in tool life when the cutting speed is reduced by 50% (n = 0·5 and c = 400)

(a) 300% (b) 400%

(c) 100% (d) 50%

248

GATE-2018

Using the Taylor's tool life equation with exponent n = 0.5, if the cutting speed is reduced by 50%, the ratio of new tool life to original tool life is

(a) 4 (b) 2 (c) 1 (d) 0.5

249

IES-2015

If n = 0.5 and C= 300 for the cutting speed and the tool life relation, when cutting speed is reduced by 25% , if the tool life is increased by

a) 100%

b) 95%

c) 78%

d) 50%

250

IES-2013

A carbide tool(having *n* = 0.25) with a mild steel work-piece was found to give life of 1 hour 21 minutes while cutting at 60 m/min. The value of C in Taylor's tool life equation would be equal to:

(*a*) 200

(*b*) 180

(*c*) 150

(*d*) 100

251

IAS – 1997

In the Taylor's tool life equation, VT^n = C, the value of n = 0.5. The tool has a life of 180 minutes at a cutting speed of 18 m/min. If the tool life is reduced to 45 minutes, then the cutting speed will be

(a) 9 m/min (b) 18 m/min

(c) 36 m/min (d) 72 m/min

252

IES – 2006 conventional

An HSS tool is used for turning operation. The tool life is 1 hr. when turning is carried at 30 m/min. The tool life will be reduced to 2.0 min if the cutting speed is doubled. Find the suitable speed in RPM for turning 300 mm diameter so that tool life is 30 min.

253

GATE-2009 Linked Answer Questions (1)

In a machining experiment, tool life was found to vary with the cutting speed in the following manner:

Cutting speed (m/min)	Tool life (minutes)
60	81
90	36

The exponent (n) and constant (k) of the Taylor's tool life equation are

(a) n = 0.5 and k = 540 (b) n= 1 and k=4860

(c) n = -1 and k = 0.74 (d) n-0.5 and k=1.15

254

GATE-2009 Linked Answer Questions (2)

In a machining experiment, tool life was found to vary with the cutting speed in the following manner:

Cutting speed (m/min)	Tool life (minutes)
60	81
90	36

What is the percentage increase in tool life when the cutting speed is halved?

(a) 50% (b) 200%

(c) 300% (d) 400%

255

IFS-2013

In a metal cutting experiment, the tool life was found to vary with the cutting speed in the following manner :

Cutting speed, V (in m/min)	Tool life, T(in min)
100	120
130	50

Derive Taylor's tool life equation for this operation and estimate the tool life at a speed of 2.5 m/s. Also estimate the cutting speed for a tool life of 80 min.

256

GATE-2010

For tool A, Taylor's tool life exponent (n) is 0.45 and constant (K) is 90. Similarly for tool B, n = 0.3 and K = 60. The cutting speed (in m/min) above which tool A will have a higher tool life than tool B is

(a) 26.7 (b) 42.5 (c) 80.7 (d) 142.9

257

GATE-2013

Two cutting tools are being compared for a machining operation. The tool life equations are:

Carbide tool: $VT^{1.6} = 3000$

HSS tool: $VT^{0.6} = 200$

Where V is the cutting speed in m/min and T is the tool life in min. The carbide tool will provide higher tool life if the cutting speed in m/min exceeds

(a) 15.0 (b) 39.4 (c) 49.3 (d) 60.0

258

GATE-2017

Two cutting tools with tool life equations given below are being compared:

Tool 1: $VT^{0.1} = 150$

Tool 2: $VT^{0.3} = 300$

Where V is cutting speed in m/minute and T is tool life in minutes. The breakeven cutting speed beyond which Tool 2 will have a higher tool life is ____ m/minute.

259

Example

The following data was obtained from the tool-life cutting test:

Cutting Speed, m/min:	49.74	49.23	48.67	45.76	42.58
Tool life, min	2.94	3.90	4.77	9.87	28.27

Determine the constants of the Taylor tool life equation $VT^n = C$

260

GATE-2003

A batch of 10 cutting tools could produce 500 components while working at 50 rpm with a tool feed of 0.25 mm/rev and depth of cut of 1 mm. A similar batch of 10 tools of the same specification could produce 122 components while working at 80 rpm with a feed of 0.25 mm/rev and 1 mm depth of cut. How many components can be produced with one cutting tool at 60 rpm?

(a) 29 (b) 31 (c) 37 (d) 42

261

GATE-2018

Taylor's tool life equation is used to estimate the life of a batch of identical HSS twist drills by drilling through holes at constant feed in 20 mm thick mild steel plates. In test 1, a drill lasted 300 holes at 150 rpm while in test 2, another drill lasted 200 holes at 300 rpm. The maximum number of holes that can be made by another drill from the above batch at 200 rpm is________(correct to two decimal places).

262

GATE-2017

During the turning of a 20 mm-diameter steel bar at a spindle speed of 400 rpm, a tool life of 20 minute is obtained.

When the same bar is turned at 200 rpm, the tool life becomes 60 minute. Assume that Taylor's tool life equation is valid.

When the bar is turned at 300 rpm, the tool life (in minute) is approximately

(a) 25 (b) 32 (c) 40 (d) 50

263

GATE-1999

What is approximate percentage change is the life, t, of a tool with zero rake angle used in orthogonal cutting when its clearance angle, α, is changed from 10° to 7°?

(Hint: Flank wear rate is proportional to cot α)

(a) 30 % increase (b) 30%, decrease

(c) 70% increase (d) 70% decrease

264

Extended or Modified Taylor's equation

$$VT^n f^a d^b = C$$

Where: d = depth of cut

f = feed rate

$$\text{or} \quad T = \frac{C^{1/n}}{V^{1/n}.f^{1/n_1}.d^{1/n_2}}$$

$$\frac{1}{n} > \frac{1}{n_1} > \frac{1}{n_2}$$

i.e Cutting speed has the greater effect followed by feed and depth of cut respectively.

265

IES 2010

Tool life is affected mainly with

(a) Feed

(b) Depth of cut

(c) Coolant

(d) Cutting speed

266

ISRO-2012

What is the correct sequence of the following parameters in order of their maximum to minimum influence on tool life?

1. Feed rate
2. Depth of cut
3. Cutting speed

Select the correct answer using the codes given below

(a) 1, 2, 3 (b) 3, 2, 1 (c) 2, 3, 1 (d) 3, 1, 2

267

IES – 1997

Consider the following elements:

1. Nose radius 2. Cutting speed
3. Depth of cut 4. Feed

The correct sequence of these elements in DECREASING order of their influence on tool life is

(a) 2, 4, 3, 1 (b) 4, 2, 3, 1

(c) 2,4, 1, 3 (d) 4, 2, I, 3

268

IES – 1994, 2007

For increasing the material removal rate in turning, without any constraints, what is the right sequence to adjust the cutting parameters?

1. Speed 2. Feed 3. Depth of cut

Select the correct answer using the code given below:

(a) 1- 2- 3 (b) 2- 3- 1

(c) 3- 2- 1 (d) 1- 3- 2

269

IES – 2008

What are the reasons for reduction of tool life in a machining operation?

1. **Temperature rise of cutting edge**
2. **Chipping of tool edge due to mechanical impact**
3. **Gradual wears at tool point**
4. **Increase in feed of cut at constant cutting force**

Select the correct answer using the code given below:

(a) 1, 2 and 3 (b) 2, 3 and 4

(c) 1, 3 and 4 (d) 1, 2 and 4

270

IAS – 1995

Assertion (A): An increase in depth of cut shortens the tool life.

Reason(R): Increases in depth of cut gives rise to relatively small increase in tool temperature.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

ESE-1999; IAS -2010 Conventional

The following equation for tool life was obtained for HSS tool. A 60 min tool life was obtained using the following cutting condition $VT^{0.13}f^{0.6}d^{0.3} = C$. v = 40 m/min, f = 0.25 mm, d = 2.0 mm. Calculate the effect on tool life if speed, feed and depth of cut are together increased by 25% and also if they are increased individually by 25%; where f = feed, d = depth of cut, v = speed.

GATE-2016

The tool life equation for HSS tool is $VT^{0.14} f^{0.7} d^{0.4} = C$. The tool life (T) of 30 min is obtained using the following cutting conditions: V = 45 m/min, f = 0.35 mm, d = 2.0 mm. If speed (V), feed(f) and depth of cut (d) are increased individually by 25%, the tool life (in min) is

(a) 0.15 (b) 1.06 (c) 22.50 (d) 30.0

GATE-2017 (PI)

In a machining operation with turning tool, the tool life (T) is related to cutting speed V (m/s), feed f(mm) and depth of cut d (mm) as

$$T = Cv^{-2.5} f^{-0.9} d^{-0.15}$$

Where, C is a constant. The suggested values for the cutting parameters are: V = 1.5 m/s, f = 0.25 mm and d = 3 mm for normal rough turning. If the operation is performed at twice the cutting speed and the other parameters remain unchanged, the corresponding percentage change in tool life is_____________.

IES-2016 Conventional

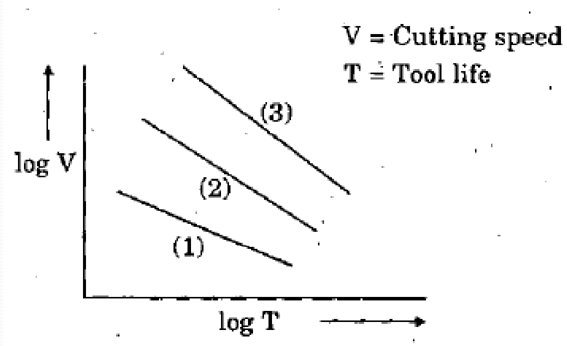
Write the generalized Taylor's tool life equation. Also write the simplified Taylor's tool life equation.

During machining of low carbon steel with HSS tool, the following observations have

Cutting speed, m/min	40	50
Tool Life, min	40	10

Derive the V-T relationship.

Tool Life Curve



1. HSS **2. Carbide** **3. Ceramic**

IFS 2009

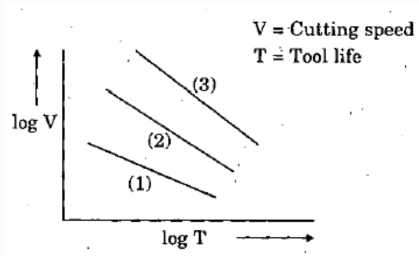
With the help of Taylor's tool life equation, determine the shape of the curve between velocity of cutting and life of the tool. Assume an HSS tool and steel as work material.

[10-Marks]

IES 2010 Conventional

Draw tool life curves for cast alloy, High speed steel and ceramic tools. [2 – Marks]

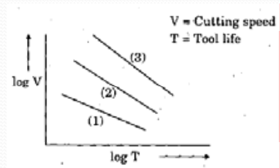
Ans.



1. High speed steel 2. cast alloy and 3. ceramic tools.

IES 2010

The above figure shows a typical relationship between tool life and cutting speed for different materials. Match the graphs for HSS, Carbide and Ceramic tool materials and select the correct answer using the code given below the lists:



Code:	HSS	Carbide	Ceramic
(a)	1	2	3
(b)	3	2	1
(c)	1	3	2
(d)	3	1	2

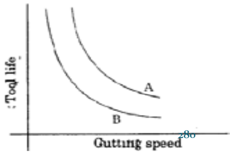
IAS – 2003

The tool life curves for two tools A and B are shown in the figure and they follow the tool life equation $VT^n = C$. Consider the following statements:

1. Value of n for both the tools is same.
2. Value of C for both the tools is same.
3. Value of C for tool A will be greater than that for the tool B.
4. Value of C for tool B will be greater than that for the tool A.

Which of these statements is/are correct?

(a) 1 and 3 (b) 1 and 4
(c) 2 only (d) 4 only



280

IFS-2015

Write Taylor's tool-life equation.

Draw tool-life curves for a variety of cutting tool materials like ceramic, high speed steel, cast alloy and carbide.

281

Cutting speed used for different tool materials

HSS (min) 30 m/min < Cast alloy < Carbide

< Cemented carbide 150 m/min < Cermets

< Ceramics or sintered oxide (max) 600 m/min

282

Effect of Rake angle on tool life

- If rake angle is large, smaller will be cutting angle and larger will be the shear angle. This will reduce force and power of cut i.e. ↑ tool life.
- But increasing the rake angle reduces the mass of metal behind the cutting edge resulting in poor transfer of heat i. e. ↓ tool life.
- Therefore optimum value of $\alpha = 14^0$.

283

Effect of Clearance angle on tool life

If clearance angle increased it reduces flank wear but weaken the cutting edge, so best compromise is 8° for HSS and 5° for carbide tool.

Effect of work piece on tool life

- With hard micro-constituents in the matrix gives poor tool life.
- With larger grain size tool life is better.

284

For IES Only

Tool life Tests

- Conventional test: Using empirical formula
- Accelerated test: Estimate the tool life quickly

Extrapolating of steady wear rate
High speed test-will take less time
Variable speed test
Multi pass turning
Taper turning

Refer: B.L Juneja+Nitin Seth

285

IES - 2014

In accelerated tool life tests, the three main types of quick and less costly tool life testing are

(a) Extrapolation on the basis of steady wear; conventional measurement of flank and crater wear; comparative performance against tool chipping

(b) Measurement of abrasive wear; multi –pass turning; conventional measurement of diffusion wear

(c) Extrapolating on the basis of steady wear, multi-pass turning; taper turning

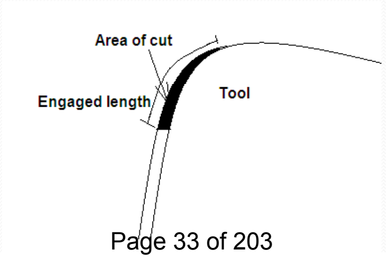
(d) comparative performance against tool chipping; taper turning; measurement of abrasive wear

286

Chip Equivalent

$$\text{Chip Equivalent}(q) = \frac{\text{Engaged cutting edge length}}{\text{Plan area of cut}}$$

- It is used for controlling the tool temperature.



287

- The SCEA alters the length of the engaged cutting edge without affecting the area of cut. As a result, the chip equivalent changed. When the SCEA is increased, the chip equivalent is increased, without significantly changing the cutting forces.
- Increase in nose radius also increases the value of the chip equivalent and improve tool life.

288

IES-1996

Chip equivalent is increased by

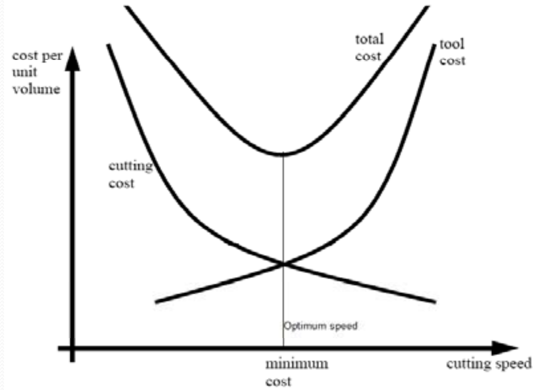
(a) An increases in side-cutting edge angle of tool

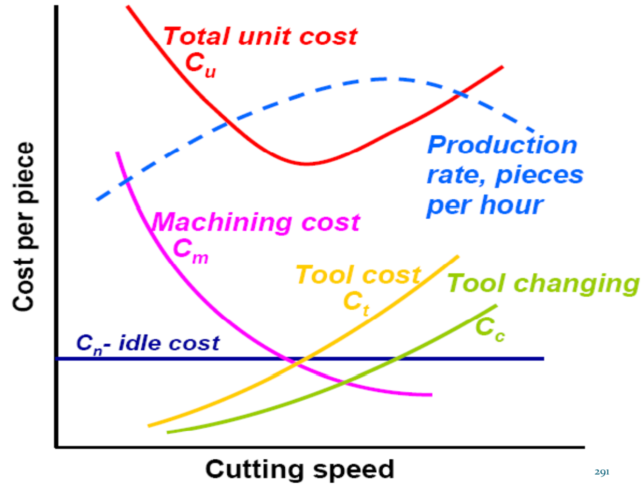
(b) An increase in nose radius and side cutting edge angle of tool

(c) Increasing the plant area of cut

(d) Increasing the depth of cut.

Economics of metal cutting





Formula

$$V_o T_o^n = C$$

Optimum tool life for minimum cost

$$T_o = \left(T_c + \frac{C_t}{C_m}\right)\left(\frac{1-n}{n}\right)$$

Optimum tool life for Maximum Productivity (minimum production time)

$$T_o = T_c\left(\frac{1-n}{n}\right)$$

Units: T_c – min (Tool changing time)

C_t – Rs./ servicing or replacement (Tooling cost)

C_m – Rs/min (Machining cost)

V – m/min (Cutting speed)

Tooling cost (C_t) = tool regrind cost + tool depreciation per service/ replacement

Machining cost (C_m) = labour cost + over head cost per min

IES 2009 Conventional

Determine the optimum cutting speed for an operation on a Lathe machine using the following information:

Tool change time: 3 min

Tool regrinds time: 3 min

Machine running cost Rs.0.50 per min

Depreciation of tool regrinds Rs. 5.0

The constants in the tool life equation are 60 and 0.2

GATE-2014

If the Taylor's tool life exponent *n* is 0.2, and the tool changing time is 1.5 min, then the tool life (in min) for maximum production rate is ....

ESE-2001 Conventional

In a certain machining operation with a cutting speed of 50 m/min, tool life of 45 minutes was observed. When the cutting speed was increased to 100 m/min, the tool life decreased to 10 min. Estimate the cutting speed for maximum productivity if tool change time is 2 minutes.

IAS – 2011 Main

Determine the optimum speed for achieving maximum production rate in a machining operation. The data is as follows :

Machining time/job = 6 min.

Tool life = 90 min.

Taylor's equation constants C = 100, n = 0.5

Job handling time = 4 min./job

Tool changing time = 9 min.

[10-Marks]

Example

A 600 mm long job of diameter 150 mm is turned with feed 0.25 mm/rev and depth of cut 1.5 mm.

Data: Labour cost = Rs. 12.00/hr.
Machine overhead cost = Rs. 40.00/hr.
Grinding cost = Rs. 15.00/hr.
Grinding machine overhead = Rs. 50/hr.
Idle time = 5 min
Tool life constants are 0.22 and 475
For tool: Initial cost = Rs. 60.00
Grinding time is 5 min/edge
Tool change time 2 min
9 grinds per tool before salvage.
Find minimum production cost

Answer

Tool change time $(T_c) = 2$ min

Tool grinding cost = 5 x (15 + 50)/60 = Rs. 5.417/edge

Tool will be used 10 times (Because first grinding not needed 9 regrinding needed)

$$\text{Tooling cost}(C_t) = \frac{60 + 5.417\times 9}{10} = Rs. 10.875/\text{ use of tool}$$

$$\text{Machining cost}(C_m) = \text{Labour cost} + \text{Overhead cost per min}$$
$$= (12+40)/60 = \text{Rs. } 0.8667/\text{min}$$

$$\text{Optimum tool life } (T_o) = \left(T_c + \frac{C_t}{C_m}\right)\left(\frac{1-n}{n}\right)$$
$$= \left(2 + \frac{10.875}{0.8667}\right)\left(\frac{1-0.22}{0.22}\right) = 51.58\text{ min}$$

$$\text{Optimum Speed}(V_o) = \frac{C}{T_o^n} = \frac{475}{51.58^{0.22}} = 199.5\text{ m/min}$$

Answer(Contd....)

$$\text{Machining time } (T_m) = \frac{\pi DL}{1000 fV} = \frac{\pi\times 150\times 600}{1000\times 0.25\times 199.5} = 5.669\text{ min}$$

$$\text{Total time}(T_{total}) = \text{Idle time}(t_o) + \frac{\text{Initial setup time for a batch}(t_i)}{\text{Number of parts produced per batch}(p)}$$
$$+ \text{Machining time}(T_m) + \text{Tool change time}(T_c)\times\frac{\text{Machining time}(T_m)}{\text{Optimum tool life}(T_o)}$$

$$= 5 + 0 + 5.669 + 2\times\frac{5.669}{51.58} = 10.89\text{ min}$$

$$\text{Cost of Operation} = C_m\left(t_o + \frac{t_i}{p} + T_m\right) + (C_t + T_c\times C_m)\times\frac{T_m}{T_o}$$
$$= 0.8667\times(5+0+5.667) + (10.875 + 2\times 0.8667)\times\frac{5.667}{51.58}$$
$$= Rs. 10.63\text{ per piece}$$

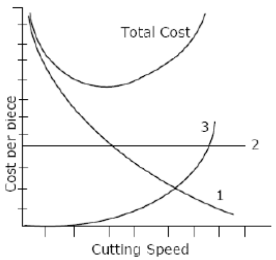
GATE-2016

For a certain job, the cost of metal cutting is Rs. 18C/V and the cost of tooling is Rs. 270C/(TV), where C is a constant, V is cutting speed in m/min and T is the tool life in minutes. The Taylor's tool life equation is $VT^{0.25}$ = 150. The cutting speed (in m/min) for the minimum total cost is ________

GATE-2005

The figure below shows a graph which qualitatively relates cutting speed and cost per piece produced.
The three curves 1, 2 and 3 respectively represent

(a) Machining cost, non-productive cost, tool changing cost
(b) Non-productive cost, machining cost, tool changing cost
(c) Tool changing cost, machining cost, non-productive cost
(d) Tool changing cost, non-productive cost, machining cost



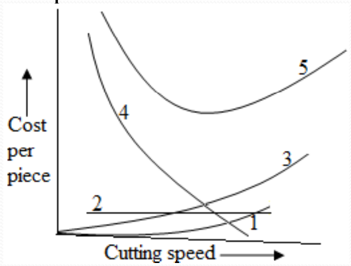
[GATE-2005]

IAS – 2007 Contd...

A diagram related to machining economics with various cost components is given above. Match List I (Cost Element) with List II (Appropriate Curve) and select the correct answer using the code given below the Lists:

List I (Cost Element)		List II (Appropriate Curve)	
A.	Machining cost	1.	Curve-l
B.	Tool cost	2.	Curve-2
C.	Tool grinding cost	3.	Curve-3
D.	Non-productive cost	4.	Curve-4
		5.	Curve-5

Contd.......... From previous slide



Code:	A	B	C	D		A	B	C	D
(a)	3	2	4	5	(b)	4	1	3	2
(c)	3	1	4	2	(d)	4	2	3	5

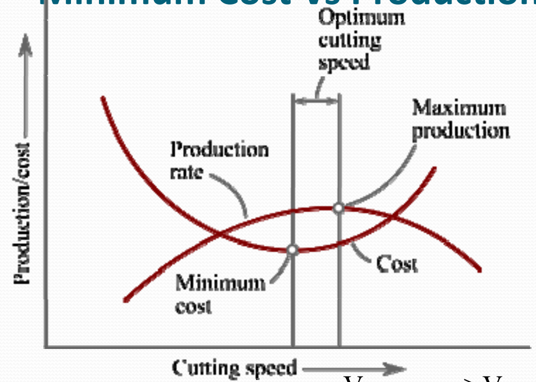
IES 2011

The optimum cutting speed is one which should have:

1. High metal removal rate
2. High cutting tool life
3. Balance the metal removal rate and cutting tool life

(a) 1, 2 and 3
(b) 1 and 2 only
(c) 2 and 3 only
(d) 3 only

Minimum Cost Vs Production Rate



$$V_{max.\,production} > V_{max\,profit} > V_{min.\,cost}$$

IES – 1999

Consider the following approaches normally applied for the economic analysis of machining:

1. **Maximum production rate**
2. **Maximum profit criterion**
3. **Minimum cost criterion**

The correct sequence in ascending order of optimum cutting speed obtained by these approaches is

(a) 1, 2, 3 (b) 1, 3, 2

(c) 3, 2, 1 (d) 3, 1, 2

IES – 1998

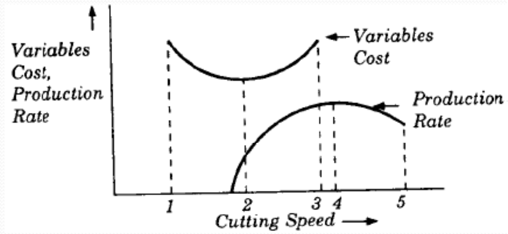
The variable cost and production rate of a machining process against cutting speed are shown in the given figure. For efficient machining, the range of best cutting speed would be between

(a) 1 and 3

(b) 1 and 5

(c) 2 and 4

(d) 3 and 5



IAS – 2002

Optimum cutting speed for minimum cost ($V_{c\ min}$) and optimum cutting speed for maximum production rate ($V_{r\ max}$) have which one of the following relationships?

(a) $V_{c\ min} = V_{r\ max}$ (b) $V_{c\ min} > V_{r\ max}$

(c) $V_{c\ min} < V_{r\ max}$ (d) $V^2_{c\ min} = V_{r\ max}$

IAS – 1997

In turning, the ratio of the optimum cutting speed for minimum cost and optimum cutting speed for maximum rate of production is always

(a) Equal to 1

(b) In the range of 0.6 to 1

(c) In the range of 0.1 to 0.6

(d) Greater than 1

IES – 2000

The magnitude of the cutting speed for maximum profit rate must be

(a) In between the speeds for minimum cost and maximum production rate

(b) Higher than the speed for maximum production rate

(c) Below the speed for minimum cost

(d) Equal to the speed for minimum cost

IES – 2004

Consider the following statements:

1. As the cutting speed increases, the cost of production initially reduces, then after an optimum cutting speed it increases
2. As the cutting speed increases the cost of production also increases and after a critical value it reduces
3. Higher feed rate for the same cutting speed reduces cost of production
4. Higher feed rate for the same cutting speed increases the cost of production

Which of the statements given above is/are correct?

(a) 1 and 3 (b) 2 and 3

(c) 1 and 4 (d) 3 only

IES – 2002

In economics of machining, which one of the following costs remains constant?

(a) Machining cost per piece

(b) Tool changing cost per piece

(c) Tool handling cost per piece

(d) Tool cost per piece

IAS – 2007

Assertion (A): The optimum cutting speed for the minimum cost of machining may not maximize the profit.

Reason (R): The profit also depends on rate of production.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES 2010

With increasing cutting velocity, the total time for machining a component

(a) Decreases

(b) Increases

(c) Remains unaffected

(d) First decreases and then increases

Machinability

Machinability-Definition

Machinability can be tentatively defined as 'ability of being machined' and more reasonably as 'ease of machining'.

Such ease of machining or machining characters of any tool-work pair is to be judged by:

- Tool wear or tool life
- Magnitude of the cutting forces
- Surface finish
- Magnitude of cutting temperature
- Chip forms.

Free Cutting steels

- Addition of lead in low carbon re-sulphurised steels and also in aluminium, copper and their alloys help reduce their τ_s. The dispersed lead particles act as discontinuity and solid lubricants and thus improve machinability by reducing friction, cutting forces and temperature, tool wear and BUE formation.
- It contains less than 0.35% lead by weight .
- A free cutting steel contains

C-0.07%, Si-0.03%, Mn-0.9%, P-0.04%, S-0.22%, Pb-0.15%

Machinability Index Or Machinability Rating

The machinability index K_M is defined by

$$K_M = V_{60}/V_{60R}$$

Where V_{60} is the cutting speed for the target material that ensures tool life of 60 min, V_{60R} is the same for the reference material.

If $K_M > 1$, the machinability of the target material is better that this of the reference material, and vice versa

IES - 2012

The usual method of defining machinability of a material is by an index based on

(a) Hardness of work material

(b) Production rate of machined parts

(c) Surface finish of machined surfaces

(d) Tool life

IAS – 1996

Assertion (A): The machinability of a material can be measured as an absolute quantity.

Reason (R): Machinability index indicates the ease with which a material can be machined

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

Machinability of Steel

- Mainly *sulfur* and *lead* improve machinability of steel.
- **Resulfurized steel:** Sulfur is added to steel only if there is sufficient manganese in it. Sulfur forms manganese sulfide which exists as an isolated phase and act as internal lubrication and chip breaker.
- If insufficient manganese is there a low melting iron sulfide will formed around the austenite grain boundary. Such steel is very weak and brittle.
- *Tellurium* and *selenium* is similar to sulfur.

Machinability of Steel contd...

- **Leaded steel:** Lead is insoluble and takes the form of dispersed fine particle and act as solid lubricants. At high speed lead melts and acting as a liquid lubricants. As lead is toxin and pollutant, lead free steel is produced using *Bismuth* and *Tin*.
- **Rephosphorized steel:** Phosphorus strengthens the ferrite, causing increased hardness, result in better chip formation and surface finish.
- **Calcium-Deoxidized steel:** Oxide flakes of calcium silicates are formed. Reduce friction, tool temp, crater wear specially at high speed.

Machinability of Steel contd...

- **Stainless Steel:** Difficult to machine due to abrasion.
- **Aluminum and Silicon in steel:** Reduce machinability due to aluminum oxide and silicates formation, which are hard and abrasive.
- **Carbon and manganese in steel:** Reduce machinability due to more carbide.
- **Nickel, Chromium, molybdenum, and vanadium in steel:** Reduce machinability due to improved property.
- Effect of *boron* is negligible. *Oxygen* improve machinability. *Nitrogen* and *Hydrogen* reduce machinability.

For IES Only

IES 2011 Conventional

Discuss the effects of the following elements on the machinability of steels:

(i) Aluminium and silicon

(ii) Sulphur and Selenium

(iii) Lead and Tin

(iv) Carbon and Manganese

(v) Molybdenum and Vanadium [5 Marks]

325

For IES Only

Role of microstructure on Machinability

Coarse microstructure leads to lesser value of τ_s.

Therefore, τ_s can be desirably reduced by

- Proper heat treatment like annealing of steels
- Controlled addition of materials like sulphur (S), lead (Pb), Tellerium etc leading to free cutting of soft ductile metals and alloys.
- **Brittle materials are relatively more machinable.**

326

IES – 1992

Tool life is generally better when

(a) Grain size of the metal is large

(b) Grain size of the metal is small

(c) Hard constituents are present in the microstructure of the tool material

(d) None of the above

327

For IES Only

Effects of tool rake angle(s) on machinability

- As Rake angle increases machinability increases.
- But too much increase in rake weakens the cutting edge.

328

IAS – 2000

Consider the following statements:

The tool life is increased by

1. Built -up edge formation
2. Increasing cutting velocity
3. Increasing back rake angle up to certain value

Which of these statements are correct?

(a) 1 and 3 (b) 1 and 2

(c) 2 and 3 (d) 1, 2 and 3

329

For IES Only

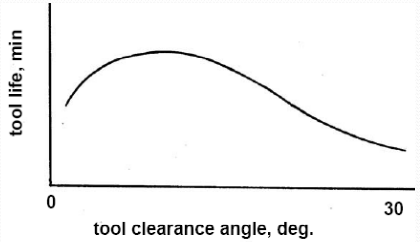
Effects of Cutting Edge angle(s) on machinability

- The variation in the cutting edge angles does not affect cutting force or specific energy requirement for cutting.
- Increase in SCEA and reduction in ECEA improves surface finish sizeably in continuous chip formation hence Machinability.

330

For IES Only

Effects of clearance angle on machinability



Inadequate clearance angle reduces tool life and surface finish by tool – work rubbing, and again too large clearance reduces the tool strength and tool life hence machinability.

331

For IES Only

Effects of Nose Radius on machinability

Proper tool nose radiusing improves machinability to some extent through

- increase in tool life by increasing mechanical strength and reducing temperature at the tool tip
- reduction of surface roughness, h_{max}

$$h_{max} = \frac{f^2}{8R}$$

332

IES – 1992

Ease of machining is primarily judged by

(a) Life of cutting tool between sharpening

(b) Rigidity of work -piece

(c) Microstructure of tool material

(d) Shape and dimensions of work

333

IES – 2007, 2009

Consider the following:

1. Tool life
2. Cutting forces
3. Surface finish

Which of the above is/are the machinability criterion/criteria?

(a) 1, 2 and 3 (b) 1 and 3 only

(c) 2 and 3 only (d) 2 only

334

ISRO-2007

Machinability depends on

(a) Microstructure, physical and mechanical properties and composition of workpiece material.

(b) Cutting forces

(c) Type of chip

(d) Tool life

335

IES – 2003

Assertion (A): The machinability of steels improves by adding sulphur to obtain so called 'Free Machining Steels'.

Reason (R): Sulphur in steel forms manganese sulphide inclusion which helps to produce thin ribbon like continuous chip.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

336

IES – 2009

The elements which, added to steel, help in chip formation during machining are

(a) Sulphur, lead and phosphorous

(b) Sulphur, lead and cobalt

(c) Aluminium, lead and copper

(d) Aluminium, titanium and copper

337

IES – 1998

Consider the following criteria in evaluating machinability:

1. Surface finish 2. Type of chips

3. Tool life 4. Power consumption

In modern high speed CNC machining with coated carbide tools, the correct sequence of these criteria in DECREASING order of their importance is

(a) 1, 2, 4, 3 (b) 2, 1, 4, 3

(c) 1, 2, 3, 4 (d) 2, 1, 3, 4

338

IES – 1996

Which of the following indicate better machinability?

1. **Smaller shear angle**
2. **Higher cutting forces**
3. **Longer tool life**
4. **Better surface finish.**

(a) 1 and 3 (b) 2 and 4

(c) 1 and 2 (d) 3 and 4

339

IES – 1996

Small amounts of which one of the following elements/pairs of elements is added to steel to increase its machinability?

(a) Nickel (b) Sulphur and phosphorus

(c) Silicon (d) Manganese and copper

340

IES – 1995

In low carbon steels, presence of small quantities sulphur improves

(a) Weldability (b) Formability

(c) Machinability (d) Hardenability

341

For IES Only

Machinability of Titanium

- Titanium is very reactive and the chips tend to weld to the tool tip leading to premature tool failure due to edge chipping.
- Titanium and its alloys have poor thermal conductivity, causing high temperature rise and BUE.
- Almost all tool materials tend to react chemically with titanium.

342

IES – 1992

Machining of titanium is difficult due to

(a) High thermal conductivity of titanium

(b) Chemical reaction between tool and work

(c) Low tool-chip contact area

(d) None of the above

343

IES – 2013 Conventional

Why does titanium have poor machinability?

344

IES -1995

Consider the following work materials:

1. Titanium 2. Mild steel
3. Stainless steel 4. Grey cast iron.

The correct sequence of these materials in terms of increasing order of difficulty in machining is

(a) 4, 2, 3, 1 (b) 4, 2, 1, 3
(c) 2, 4, 3, 1 (d) 2, 4, 1, 3

345

Surface Roughness

- **Ideal Surface (Zero nose radius)**

Peak to valley roughness (h) = $\dfrac{f}{\tan SCEA + \cot ECEA}$

and $(R_a) = \dfrac{h}{4} = \dfrac{f}{4(\tan SCEA + \cot ECEA)}$

- **Practical Surface (with nose radius = R)**

$h = \dfrac{f^2}{8R}$ and $R_a = \dfrac{f^2}{18\sqrt{3}R}$

Change in feed (f) is more important than a change in nose radius (R) and depth of cut has no effect on surface roughness.

346

IES - 2002

The value of surface roughness 'h' obtained during the turning operating at a feed 'f' with a round nose tool having radius 'r' is given as

(a) $\dfrac{f}{8r}$ (b) $\dfrac{f^2}{8r}$

(c) $\dfrac{f^3}{8r}$ (d) $\dfrac{f^3}{8r^2}$

347

IAS - 1996

Given that

S = feed in mm/rev. and

R = nose radius in mm,

the maximum height of surface roughness H_{max} produced by a single-point turning tool is given by

(a) $S^2/2R$

(b) $S^2/4R$

(c) $S^2/4R$

(d) $S^2/8R$

348

IES - 1999

In turning operation, the feed could be doubled to increase the metal removal rate. To keep the same level of surface finish, the nose radius of the tool should be

(a) Halved (b) Kept unchanged

(c) doubled (d) Made four times

349

GATE - 1997

A cutting tool has a radius of 1.8 mm. The feed rate for a theoretical surface roughness of is 5 μm is

(a) 0.268 mm/rev

(b) 0.187 mm/rev

(c) 0.036 mm/rev

(d) 0.0187 mm/rev

350

GATE – 2007 (PI)

A tool with Side Cutting Edge angle of 30° and End Cutting Edge angle of 10° is used for fine turning with a feed of 1 mm/rev. Neglecting nose radius of the tool, the maximum (peak to valley) height of surface roughness produced will be

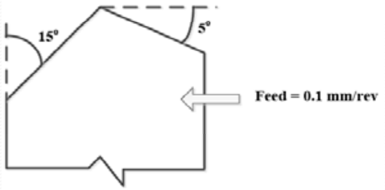
(a) 0.16 mm (b) 0.26 mm

(c) 0.32 mm (d) 0.48 mm

351

GATE-2018 (PI)

A cylindrical workpiece is turned at a feed of 0.1 mm/rev with a perfectly sharp tool. In ASA system, the side and end cutting edge angles are 15° and 5°, respectively, as shown in the figure. The peak-to-valley roughness (in μm, up to one decimal place) of the machined surface is ______



352

GATE - 2005

Two tools P and Q have signatures 5°-5°-6°-6°-8°-30°-0 and 5°-5°-7°-7°-8°-15°-0 (both ASA) respectively. They are used to turn components under the same machining conditions. If h_p and h_Q denote the peak-to-valley heights of surfaces produced by the tools P and Q, the ratio h_p/h_Q will be

(a) $\dfrac{\tan 8^o + \cot 15^o}{\tan 8^o + \cot 30^o}$ (b) $\dfrac{\tan 15^o + \cot 8^o}{\tan 30^o + \cot 8^o}$

(c) $\dfrac{\tan 15^o + \cot 7^o}{\tan 30^o + \cot 7^o}$ (d) $\dfrac{\tan 7^o + \cot 15^o}{\tan 7^o + \cot 30^o}$

353

IES – 1993, ISRO-2008

For achieving a specific surface finish in single point turning the most important factor to be controlled is

(a) Depth of cut (b) Cutting speed

(c) Feed (d) Tool rake angle

354

IES - 2006

In the selection of optimal cutting conditions, the requirement of surface finish would put a limit on which of the following?

(a) The maximum feed

(b) The maximum depth of cut

(c) The maximum speed

(d) The maximum number of passes

355

GATE-2014 (PI)

A spindle speed of 300 rpm and a feed of 0.3 mm/revolution are chosen for longitudinal turning operation on an engine lathe. In finishing pass, roughness on the work surface can be reduced by

(a) reducing the spindle speed

(b) increasing the spindle speed

(c) reducing the feed of tool

(d) increasing the feed of tool

356

GATE -2010 (PI)

During turning of a low carbon steel bar with TiN coated carbide insert, one need to improve surface finish without sacrificing material removal rate. To achieve improved surface finish, one should

(a) decrease nose radius of the cutting tool and increase depth of cut

(b) Increase nose radius of the cutting tool

(c) Increase feed and decrease nose radius of the cutting tool

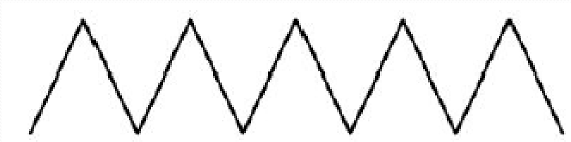
(d) Increase depth of cut and increase feed

357

GATE-2017

Assume that the surface roughness profile is triangular as shown schematically in the figure. If the peak to valley height is 20 μm, the central line average surface roughness R_a (in μm) is

(a) 5 (b) 6.67 (c) 10 (d) 20



358

Cutting fluid

- The cutting fluid acts primarily as a coolant and secondly as a lubricant, reducing the friction effects at the tool-chip interface and the work-blank regions.
- **Cast Iron:** Machined dry or compressed air, Soluble oil for high speed machining and grinding
- **Brass:** Machined dry or straight mineral oil with or without EPA.
- **Aluminium:** Machined dry or kerosene oil mixed with mineral oil or soluble oil
- **Stainless steel and Heat resistant alloy:** High performance soluble oil or neat oil with high concentration with chlorinated EP additive.

359

IAS -2009 Main

- What are extreme-pressure lubricants?

[3 – marks]

Where high pressures and rubbing action are encountered, hydrodynamic lubrication cannot be maintained; so Extreme Pressure (EP) additives must be added to the lubricant. EP lubrication is provided by a number of chemical components such as boron, phosphorus, sulfur, chlorine, or combination of these. The compounds are activated by the higher temperature resulting from extreme pressure. As the temperature rises, EP molecules become reactive and release derivatives such as iron chloride or iron sulfide and forms a solid protective coating.

360

IES - 2001

Dry and compressed air is used as cutting fluid for machining

(a) Steel (b) Aluminium
(c) Cast iron (d) Brass

361

IES - 2012

The most important function of the cutting fluid is to

(a) Provide lubrication
(b) Cool the tool and work piece
(c) Wash away the chips
(d) Improve surface finish

362

363

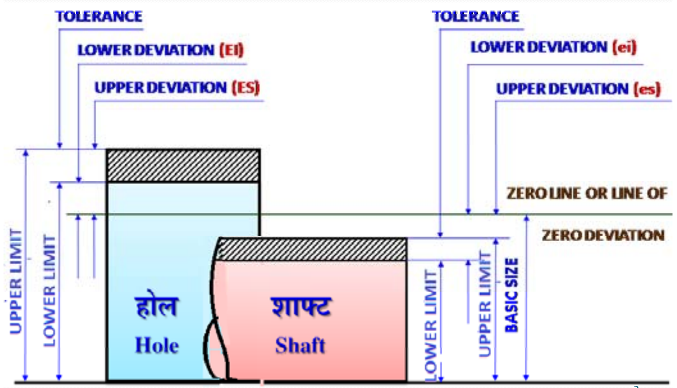
Limit, Tolerance & Fits

By S K Mondal

Metrology

- The science of measurement.
- The purpose of this discipline is to establish means of determining physical quantities, such as dimensions, temperature, force, etc.

Terminology



IAS 2014 (Main)

According to the ISO system, sketch the basic size, deviation, and tolerance on a shaft and hole assembly.

Terminology

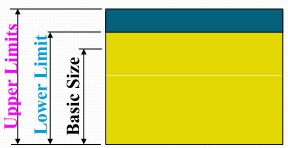
- **Nominal size**: Size of a part specified in the drawing. It is used for general identification purpose.
- **Basic size:** Size of a part to which all limits of variation (i.e. tolerances) are applied. Basic dimension is theoretical dimension.
- **Actual size:** Actual measured dimension of the part. The difference between the basic size and the actual size should not exceed a certain limit, otherwise it will interfere with the interchangeability of the mating parts.

Terminology Contd....

- **Limits of sizes:** There are two extreme permissible sizes for a dimension of the part. The largest permissible size for a dimension is called upper or high or maximum limit, whereas the smallest size is known as lower or minimum limit.
- **Tolerance**
  - The difference between the upper limit and lower limit.
  - It is the maximum permissible variation in a dimension.
  - The tolerance may be unilateral or bilateral.

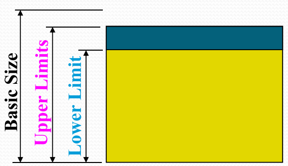
Terminology Contd....

Unilateral Limits occurs when both maximum limit and minimum limit are either above or below the basic size.



e.g. Ø25 $^{+0.18}_{+0.10}$

Basic Size = 25.00 mm
Upper Limit = 25.18 mm
Lower Limit = 25.10 mm
Tolerance = **0.08 mm**



e.g. Ø25 $^{-0.10}_{-0.20}$

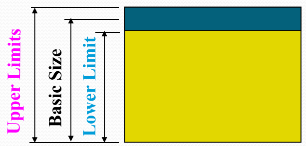
Basic Size = 25.00 mm
Upper Limit = 24.90 mm
Lower Limit = 24.80 mm
Tolerance = **0.10 mm**

Terminology Contd....

For **Unilateral Limits**, a case may occur when one of the limits ***coincides*** with the basic size,

e.g. Ø25 $^{+0.20}_{0}$, Ø25 $^{0}_{-0.10}$

Bilateral Limits occur when the maximum limit is above and the minimum limit is below the basic size.



e.g. Ø25 $^{\pm0.04}$
Basic Size = 25.00 mm
Upper Limit = 25.04 mm
Lower Limit = 24.96 mm
Tolerance = 0.08 mm

For PSU

Tolerances are specified

(a) To obtain desired fits
(b) because it is not possible to manufacture a size exactly
(c) to obtain higher accuracy
(d) to have proper allowances

ISRO-2010

Expressing a dimension as $25.3^{\pm 0.05}$ mm is the case of

(a) Unilateral tolerance

(b) Bilateral tolerance

(c) Limiting dimensions

(d) All of the above

Terminology Contd....

- **Zero line: A** straight line corresponding to the basic size. The deviations are measured from this line.
- **Deviation: I**s the algebraic difference between a size (actual, max. etc.) and the corresponding basic size.
- **Actual deviation: I**s the algebraic difference between an actual size and the corresponding basic size.
- **Upper deviation: I**s the algebraic difference between the maximum size and the basic size.

Terminology Contd....

- **Lower deviation: I**s the algebraic difference between the minimum size and the basic size.
- **Mean deviation: I**s the arithmetical mean of upper and lower deviations.
- **Fundamental deviation:** This is the deviation, either the upper or the lower deviation, which is nearest one to zero line for either a hole or shaft.

GATE – 2010, ISRO-2012

A shaft has a dimension, $\phi 35^{-0.009}_{-0.025}\ mm$

The respective values of fundamental deviation and tolerance are

(a) $-0.025, \pm 0.008$ (b) $-0.025, 0.016$

(c) $-0.009, \pm 0.008$ (d) $-0.009, 0.016$

GATE - 1992

Two shafts A and B have their diameters specified as 100 ± 0.1 mm and 0.1 ± 0.0001 mm respectively.

Which of the following statements is/are true?

(a) Tolerance in the dimension is greater in shaft A

(b) The relative error in the dimension is greater in shaft A

(c) Tolerance in the dimension is greater in shaft B

(d) The relative error in the dimension is same for shaft A and shaft B

GATE - 2004

In an interchangeable assembly, shafts of size

$25.000^{+0.040}_{-0.0100}$ **mm mate with holes of size** $25.000^{+0.020}_{-0.000}$ **mm.**

The maximum possible clearance in the assembly will be

(a) 10 microns (b) 20 microns

(c) 30 microns (d) 60 microns

IES - 2005

The tolerance specified by the designer for the diameter of a shaft is 20.00 ± 0.025 mm. The shafts produced by three different machines A, B and C have mean diameters of 19·99 mm, 20·00 mm and 20.01 mm respectively, with same standard deviation. What will be the percentage rejection for the shafts produced by machines A, B and C?

(a) Same for the machines A, Band C since the standard deviation is same for the three machines

(b) Least for machine A

(c) Least for machine B

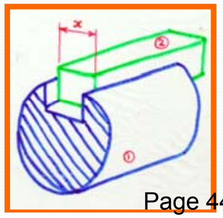
(d) Least for machine C

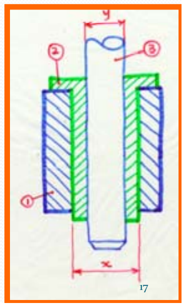
Fit

Fits: (assembly condition between "Hole" & "Shaft")

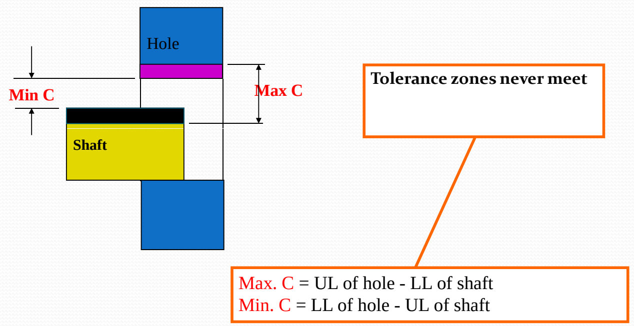
Hole – A feature engulfing a component

Shaft – A feature being engulfed by a component





Clearance Fits



The clearance fits may be slide fit, easy sliding fit, running fit, slack running fit and loose running fit

Use

- Machine tools spindles
- Pistons of hydraulic machines
- Piston cylinder in IC engine
- Inner and outer races of ball, roller and journal bearing
- Clutch disks
- Sliding rod
- Crankshaft journals
- Bolts
- Rivets
- Pivots
- Latches
- Fits of parts exposed to corrosive effects

19

GATE - 2007

A hole is specified as $40^{0.050}_{0.000}$ mm. The mating shaft has a clearance fit with minimum clearance of 0.01 mm. The tolerance on the shaft is 0.04 mm. The maximum clearance in mm between the hole and the shaft is

(a) 0.04 (b) 0.05

(c) 0.10 (d) 0.11

20

GATE-2015

Holes of diameter $25^{+0.040}_{+0.020}$ mm are assembled interchangeably with the pins of diameter $25^{+0.005}_{-0.008}$ mm. The minimum clearance in the assembly will be

a) 0.048 mm b) 0.015 mm

c) 0.005 mm d) 0.008 mm

21

IES-2015

A hole and a shaft have a basic size of 25 mm and are to have a clearance fit with a maximum clearance of 0.02 mm and a minimum clearance of 0.01 mm. The hole tolerance is to be 1.5 times the shaft tolerance. The limits of both hole and shaft using hole basis system will be

a) low limit of hole = 25 mm, high limit of hole = 25.006 mm, upper limit of shaft = 24.99 mm and low limit of shaft = 24-986 mm

b) low limit of hole = 25 mm, high limit of hole = 25.026 mm, upper limit of shaft = 24.8 mm and low limit of shaft = 24.76 mm

c) low limit of hole = 24 mm, high limit of hole = 25.006 mm, upper limit of shaft = 25 mm and low limit of shaft = 24.99 mm

d) low limit of hole = 25.006 mm, high Ch limit of hole = 25 mm, upper limit of shaft = 24.99 mm and low limit of shaft = 25 mm

22

IAS-2015 Main

A 20 mm diameter shaft and bearing are to be assembled with a clearance fit. The tolerance and allowances are as under :

Allowance = 0.002 mm

Tolerance on hole = 0.005 mm

Tolerance on shaft = 0.003 mm

Find the limits of size for the hole and shaft, if

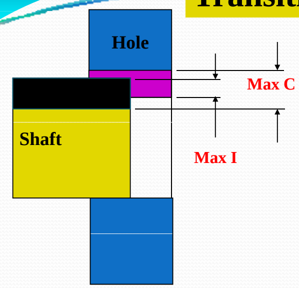
(i) the hole basis system is used,

(ii) the shaft basis system is used.

The tolerances are disposed off unilaterally.

[10 –Marks]

Transition Fits



Tolerance zones always overlap

Max. C = UL of hole - LL of shaft
Max. I = LL of hole - UL of shaft

The transition fits may be tight fit and push fit, wringing fit (Gear, pulley on shaft), press fit.

24

IES-2015

Consider the following statements

In case of assembly of mating parts

1. The difference between hole size and shaft size is called allowance.
2. In transition fit, small positive or negative clearance between the shaft and hole member is employable

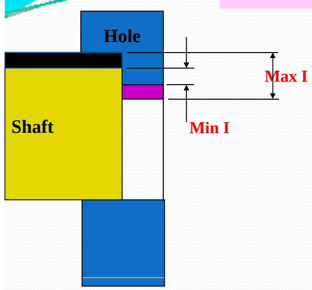
Which of the above statements is/are correct?

(a) 1 only (b) Both 1 and 2

(c) 2 only (d) Neither 1 nor 2

25

Interference Fits



Tolerance zones never meet but crosses each other

Max. I = LL of hole - UL of shaft
Min. I = UL of hole - LL of shaft

The interference fits may be shrink fit, heavy drive fit and light drive fit.

26

IES 2011

Interference fit joints are provided for:

(a) Assembling bush bearing in housing

(b) Mounting heavy duty gears on shafts

(c) Mounting pulley on shafts

(d) Assembly of flywheels on shafts

27

IES-2013

Which of the following is a joint formed by interference fits?

(*a*) Joint of cycle axle and its bearing

(*b*) Joint between I.C. Engine piston and cylinder

(*c*) Joint between a pulley and shaft transmitting power

(*d*) Joint of lathe spindle and its bearing

28

GATE - 2005

In order to have interference fit, it is essential that the lower limit of the shaft should be

(a) Greater than the upper limit of the hole

(b) Lesser than the upper limit of the hole

(c) Greater than the lower limit of the hole

(d) Lesser than the lower limit of the hole

29

IES - 2014

Statement-I: In interference fit, the outer diameter of the inner cylinder will be more than the inner diameter of the hollow outer cylinder

Statement-II: These fits are recommended for two parts frequently dismantled and assembled.

(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

30

IES-2015

Statement (I) : In interference fit, the outer diameter of the shaft is greater than the inner diameter of the hole.

Statement (II) : The amount of clearance obtained from the assembly of hole and shaft resulting in interference fit is called positive clearance.

(a) Both statement (I) and (II) are individually true and statement (II) is the correct explanation of statement (I)

(b) Both statement (I) and statement(II) are individually true but statement(II) is **not** the correct explanation of statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but statement (II) is true

31

IES-2017

Statement (I): In sugarcane crushing rollers, the fit between the cast roll and the forged steel shaft is of interference type.

Statement (II): This helps in removing the roll from the shaft whenever not needed.

(a) Both statement (I) and (II) are individually true and statement (II) is the correct explanation of statement (I)

(b) Both statement (I) and statement(II) are individually true but statement(II) is **not** the correct explanation of statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but statement (II) is true

32

GATE 2011

A hole is of dimension $\phi 9^{+0.015}_{+0}$ mm. The corresponding shaft is of dimension $\phi 9^{+0.010}_{+0.001}$ mm. The resulting assembly has

(a) loose running fit

(b) close running fit

(c) transition fit

(d) interference fit

33

GATE -2012 Same Q in GATE-2012 (PI)

In an interchangeable assembly, shafts of size $25^{+0.04}_{-0.01}$ mm mate with holes of size $25^{+0.03}_{+0.02}$ mm.

The maximum interference (in microns) in the assembly is

(a) 40 (b) 30 (c) 20 (d) 10

34

IAS-2011 Main

An interference assembly, of nominal diameter 20 mm, is of a unilateral holes and a shafts. The manufacturing tolerances for the holes are twice that for the shaft. Permitted interference values are 0.03 to 0.09 mm. Determine the sizes, with limits, for the two mating parts. [10-Marks]

Hint: Use unilateral hole basis system.

35

GATE-2018 (PI)

In a shaft-hole system, the dimensions with tolerances (in mm) are as follows:

$$Shaft: \phi 20^{+x}_{-x} \qquad Hole: \phi 20^{-0.03}_{-y}$$

where both x and y are positive real numbers. Which one of the following will provide an interference fit?

(a) x = 0.05, y = 0.040 (b) x = 0.04, y = 0.035

(c) x = 0.04, y = 0.032 (d) x = 0.02, y = 0.035

36

IES - 2007

Which one of the following is a clearance fit?

(a) $\varphi H50^{+0.015}_{+0.005}$ $h50^{-0.010}_{+0.000}$

(b) $\varphi H50^{+0.010}_{+0.000}$ $h50^{+0.025}_{+0.015}$

(c) $\varphi H50^{-0.015}_{+0.000}$ $h50^{+0.025}_{+0.005}$

(d) $\varphi H50^{-0.010}_{-0.000}$ $h50^{+0.030}_{+0.005}$

37

ISRO-2011

A shaft and hole pair is designated as 50H7d8. This assembly constitutes

(a) Interference fit

(b) Transition fit

(c) Clearance fit

(d) None of the above

38

IES - 2006

Which of the following is an interference fit?

(a) Push fit

(b) Running fit

(c) Sliding fit

(d) Shrink fit

39

IES - 2009

Consider the following joints:

1. Railway carriage wheel and axle
2. IC engine cylinder and liner

Which of the above joints is/are the result(s) of interference fit?

(a) 1 only

(b) 2 only

(c) Neither 1 nor 2

(d) Both 1 and 2

40

IES - 2008

Consider the following statements:

1. The amount of interference needed to create a tight joint varies with diameter of the shaft.
2. An interference fit creates no stress state in the shaft.
3. The stress state in the hub is similar to a thick-walled cylinder with internal pressure.

Which of the statements given above are correct?

(a) 1, 2 and 3 (b) 1 and 2 only

(c) 2 and 3 only (d) 1 and 3 only

41

IES-2015

In an interference fit between a shaft and a hub, the state of stress in the shaft due to interference fit is

a) only compressive radial stress

b) a tensile radial stress and a compressive tangential stress

c) a tensile tangential stress and a compressive radial stress

d) a compressive tangential stress and a compressive radial stress

42

IES - 2004

Consider the following fits:

1. I.C. engine cylinder and piston
2. Ball bearing outer race and housing
3. Ball bearing inner race and shaft

Which of the above fits are based on the interference system?

(a) 1 and 2

(b) 2 and 3

(c) 1 and 3

(d) 1, 2 and 3

43

IES-2015 Conventional

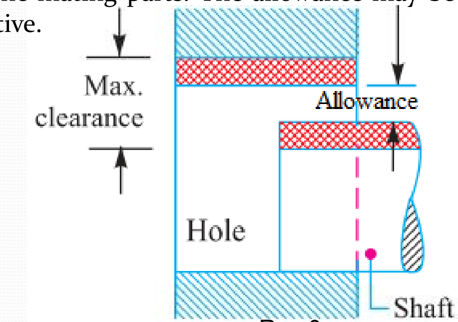
What are the different types of fits possible with reference to mechanical systems?

[4 Marks]

44

Allowance

- **It is M**inimum clearance or maximum interference. It is the ***intentional*** difference between the basic dimensions of the mating parts. The allowance may be positive or negative.



45

GATE - 2001

Allowance in limits and fits refers to

(a) Maximum clearance between shaft and hole

(b) Minimum clearance between shaft and hole

(c) Difference between maximum and minimum size of hole

(d) Difference between maximum and minimum size of shaft

46

GATE - 1998

In the specification of dimensions and fits,

(a) Allowance is equal to bilateral tolerance

(b) Allowance is equal to unilateral tolerance

(c) Allowance is independent of tolerance

(d) Allowance is equal to the difference between maximum and minimum dimension specified by the tolerance.

47

IES - 2012

Clearance in a fit is the difference between

(a) Maximum hole size and minimum shaft size

(b) Minimum hole size and maximum shaft size

(c) Maximum hole size and maximum shaft size

(d) Minimum hole size and minimum shaft size

48

IES – 2012 Conventional, IAS-2016 Main

Explain the difference between tolerance and allowance.

49

ISRO-2010

Dimension of the hole is $50^{+0.02}_{-0.00}$ mm

and shaft is $50^{+0.02}_{+0.00}$ mm.

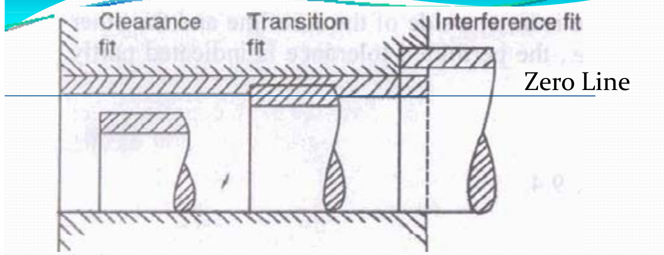
The minimum clearance is

(a) 0.02 mm (b) 0.00 mm

(c) -0.02 mm (d) 0.01 mm

50

Hole Basis System



Hole basis system

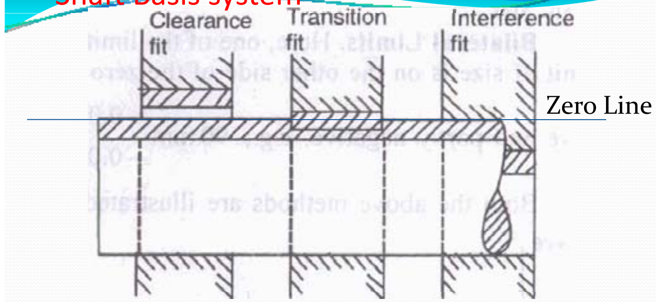
- The hole is kept as a constant member (i.e. when the lower deviation of the hole is zero)
- Different fits are obtained by varying the shaft size then the limit system is said to be on a hole basis.

51

- For hole basis system, H stands for dimensions of holes whose lower deviation is zero.
- The basic size of the hole is taken as the lower limit of size of the hole (Maximum metal condition).
- The higher limit of size of the hole and two limits of size for the shaft are then selected to give desired fits.
- The actual size of hole is always more than basic size or equal to basic size but never less than Basic size.

52

Shaft Basis system



Shaft basis system:

- When the shaft is kept as a constant member (i.e. when the upper deviation of the shaft is zero)
- Different fits are obtained by varying the hole size then the limit system is said to be on a shaft basis.

53

- For shaft basis system, h stands for dimensions of shafts whose upper deviation is zero.
- Basic size of the shaft is taken Upper limit for the shaft (Maximum metal condition)
- Lower limit of the shaft and two limits of hole are selected to give the desired fit.
- Actual size of shaft is always less than basic size or equal to basic size but never more than basic size.

54

Why Hole Basis Systems are Preferred?

- Holes can be finished by tools like reamers, drills, broaches, and their sizes are not adjustable. The shaft sizes can be easily obtained by external machining.
- If shaft basis system is used considerable no of reamers and other precision tools are required for producing different classes of holes for one class of shaft for obtaining different fits which increases cost of production.
- It is economical

ISRO-2008

Basic shaft and basic hole are those whose upper deviations and lower deviations respectively are

(a) +ve, -ve (b) -ve, +ve

(c) Zero, Zero (d) None of the above

IES - 2005

Assertion (A): Hole basis system is generally preferred to shaft basis system in tolerance design for getting the required fits.

Reason (R): Hole has to be given a larger tolerance band than the mating shaft.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IAS-2010 main

What is the difference between hole basis system and shaft basis system ? Why is hole basis system the more extensive in use ?

[8-Marks]

IFS - 2013

Explain, with the help of sketches, the concepts of hole basis and shaft basis in terms of assembly fit specifications. Which of the two is preferred and why?

[8 –Marks]

IES - 2005

Which one of the following is not correct in hole basis system of fits?

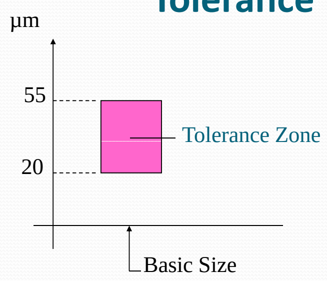
(a) The hole size is kept constant.

(b) The basic size of the hole is taken as the low limit of size of the hole.

(c) The actual size of a hole that is within the tolerance limits always less than the basic size.

(d) The high limit of the size of the hole and the two limits of size of the shaft are selected to give desired fit.

Tolerance Zone



- It is defined graphically by the magnitude of the tolerance and by its position in relation to the zero line.

Limits and Fits

- Limits and fits comprises 18 grades of fundamental tolerances for both shaft and hole, designated as IT01, IT0 and IT1 to IT16. These are called standard tolerances. (IS-919) But ISO 286 specify 20 grades upto IT18
- There are 25 (IS 919) and 28 (ISO 286) types of fundamental deviations.
  Hole: A, B, C, CD, D, E, EF, F, FG, G, H, J, JS, K, M, N, P, R, S, T, U, V, X, Y, Z, ZA, ZB, ZC.
  Shaft : a, b, c, cd, d, e, ef, f, fg, g, h, j, js, k, m, n, p, r, s, t, u, v, x, y, z, za, zb, zc.
- A unilateral hole basis system is recommended but if necessary a unilateral or bilateral shaft basis system may also be used.

Tolerance Designation (IS)

Tolerance on a shaft or a hole can be calculated by using table provided.

$$T = K \times i$$

Where, T is the tolerance (in µm)

Standard Tolerance unit or Fundamental tolerance unit

$$i = 0.45\sqrt[3]{D} + 0.001D \qquad in\ \mu m$$

$D = \sqrt{D_1 D_2}$ (D_1 and D_2 are the nominal sizes marking the beginning and the end of a range of sizes, in mm)

K = is a constant [For IT6 to IT16]

Diameter Steps

Above (mm)	Upto and including (mm)
-	3
3	6
6	10
10	18
18	30
30	50
50	80
80	120
120	180
180	250
250	315
315	400
400	500

64

Value of the Tolerance

IT01 0.3 + 0.008D	IT0 0.5 + 0.012D	IT1 0.8 + 0.02D =a	IT2 ar $r = 10^{1/5}$
IT3 ar^2	IT4 ar^3	IT5 $ar^4 = 7i$	IT6 $10(1.6)^{(IT_n - IT6)}$ = 10i
IT7 $10(1.6)^{(IT_n - IT6)}$ = 16i	IT8 $10(1.6)^{(IT_n - IT6)}$ = 25i	IT9 $10(1.6)^{(IT_n - IT6)}$ = 40i	IT10 $10(1.6)^{(IT_n - IT6)}$ = 64i
IT11 $10(1.6)^{(IT_n - IT6)}$ = 100i	IT12 $10(1.6)^{(IT_n - IT6)}$ = 160i	IT13 $10(1.6)^{(IT_n - IT6)}$ = 250i	IT14 $10(1.6)^{(IT_n - IT6)}$ = 400i
IT15 $10(1.6)^{(IT_n - IT6)}$ = 640i	IT16 $10(1.6)^{(IT_n - IT6)}$ = 1000i		

65

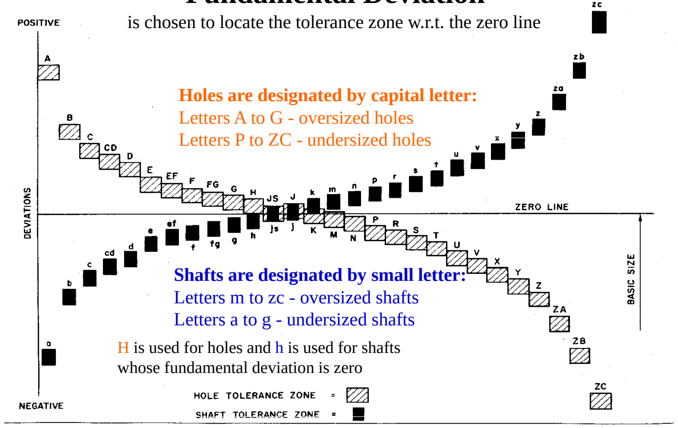
Grades of Tolerance

- It is an indication of the level of accuracy.
- IT01 to IT4 - For production of gauges, plug gauges, measuring instruments
- IT5 to IT 7 - For fits in precision engineering applications
- IT8 to IT11 – For General Engineering
- IT12 to IT14 – For Sheet metal working or press working
- IT15 to IT16 – For processes like casting, general cutting work

66

Fundamental Deviation

is chosen to locate the tolerance zone w.r.t. the zero line



67

Calculation for Upper and Lower Deviation

- **For Shaft**

  ei = es – IT

  es = ei + IT

- **For Hole**

  EI = ES – IT

  ES = EI + IT

es = upper deviation of shaft

ei = lower deviation of shaft

ES = upper deviation of hole

EI= lower deviation of hole

68

Shaft	Fundamental Deviation
a	$-(265+1.3D)$ for $D \le 120\,mm$
	$-3.5D$ for $D > 120\,mm$
b	$-(140+0.85D)$ for $D \le 160\,mm$
	$-1.8D$ for $D > 160\,mm$
c	$-52D^{0.2}$ for $D \le 40\,mm$
	$-(95+0.8D)$ for $D > 40\,mm$
d	$-16D^{0.44}$
e	$-11D^{0.41}$
f	$-5.5D^{0.41}$
g	$-2.5D^{0.41}$
h	0

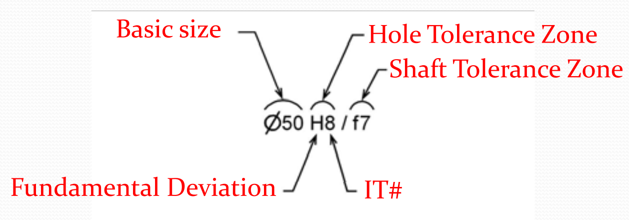
69

Shaft	Fundamental Deviation
$j5$ to $j8$	–
$k4$ to $k7$	$+0.6\sqrt[3]{D}$
m	$+(IT7 - IT6)$
n	$+5D^{0.34}$
p	$+IT7+(0-5)$
r	Geometric mean of values of ei for p and s
s	$IT8 + 1$ to 4 for $D \le 50\,mm$
	$IT7 + 0.4D$ for $D > 50\,mm$
t	$IT7 + 0.63D$
u	$IT7 + D$
v	$IT7 + 1.25D$
x	$IT7 + 1.6D$
y	$IT7 + 2D$
z	$IT7 + 2.5D$
za	$IT8 + 3.15D$
zb	$IT9 + 4D$
zc	$IT10 + 5D$

70

- For hole, H stands for a dimension whose lower deviation refers to the basic size. The hole H for which the lower deviation is zero is called a basic hole.
- Similarly, for shafts, h stands for a dimension whose upper deviation refers to the basic size. The shaft h for which the upper deviation is zero is called a basic shaft.
- A fit is designated by its basic size followed by symbols representing the limits of each of its two components, the hole being quoted first.
- For example, 100 H6/g5 means basic size is 100 mm and the tolerance grade for the hole is 6 and for the shaft is 5.

71



72

GATE-2014

For the given assembly: 25 H7/g8, match Group A with Group B

Group A	Group B
P. H	I. Shaft Type
Q. IT8	II. Hole Type
R. IT7	III. Hole Tolerance Grade
S. *g*	IV. Shaft Tolerance Grade

	P	Q	R	S		P	Q	R	S
(*a*)	I	III	IV	II	(*b*)	I	IV	III	II
(*c*)	II	III	IV	I	(*d*)	II	IV	III	I

73

IES - 2008

Consider the following statements:

A nomenclature ϕ50 H8/p8 denotes that

1. Hole diameter is 50 mm.
2. It is a shaft base system.
3. 8 indicates fundamental deviation.

Which of the statements given above is/are incorrect?

(a) 1, 2 and 3
(b) 1 and 2 only
(c) 1 and 3 only
(d) 3 only

74

IES-2006 Conventional

Find the limit sizes, tolerances and allowances for a 100 mm diameter shaft and hole pair designated by F_8h_{10}. Also specify the type of fit that the above pair belongs to.

Given: 100 mm diameter lies in the diameter step range of 80-120 mm. The fundamental deviation for shaft designation 'f' is -5.5 $D^{0.41}$

The values of standard tolerances for grades of IT 8 and IT 10 are 25i and 64i respectively.

Also, indicate the limits and tolerance on a diagram.

[15-Marks]

75

IES-2015 Conventional

Determine the fundamental deviation and tolerances and the limits of size for hole and shaft pair in the fit: 25 mm H8d9. The diameter steps are 18 mm and 30 mm. The fundamental deviation for d shaft is given as $-16D^{0.44}$. The tolerance unit is,

i = $0.45\sqrt[3]{D} + 0.001D$

The tolerance grade for number 8 quality is 25i and for 9 quality is 40i.

[10 Marks]

76

Selected Question

A journal of nominal or basic size of 75 mm runs in a bearing with close running fit H8g7. Find the limits of shaft and bearing also find maximum and minimum clearance? 75 mm lies in the diameter steps of 50 to 80 mm. Fundamental deviation for shaft g is $-2.5\ D^{0.34}$

77

IES - 2002

In the tolerance specification 25 D 6, the letter D represents

(a) Grade of tolerance
(b) Upper deviation
(c) Lower deviation
(d) Type of fit

78

GATE - 2009

What are the upper and lower limits of the shaft represented by 60 f8?

Use the following data:

Diameter 60 lies in the diameter step of 50-80 mm. Fundamental tolerance unit,

i, in μm = 0.45 $D^{1/3}$ + 0.001D, where D is the representative size in mm;

Tolerance value for IT8 = 25i.

Fundamental deviation for 'f shaft = $-5.5D^{0.41}$

(a) Lower limit = 59.924 mm, Upper Limit = 59.970 mm
(b) Lower limit = 59.954 mm, Upper Limit = 60.000 mm
(c) Lower limit = 59.970 mm, Upper Limit = 60.016 mm
(d) Lower limit = 60.000 mm, Upper Limit = 60.046 mm

79

GATE – 2008 (PI)

Following data are given for calculating limits of dimensions and tolerances for a hole: Tolerance unit i (in μm) = 0.45 $\sqrt[3]{D}$ + 0.001D. The unit of D is mm. Diameter step is 18-30 mm. If the fundamental deviation for H hole is zero and IT8 = 25 i, the maximum and minimum limits of dimension for a 25 mm H_8 hole (in mm) are

(a) 24.984, 24.967 (b) 25.017, 24.984
(c) 25.033, 25.000 (d) 25.000, 24.967

80

GATE - 2000

A fit is specified as 25H8/e8. The tolerance value for a nominal diameter of 25 mm in IT8 is 33 microns and fundamental deviation for the shaft is - 40 microns. The maximum clearance of the fit in microns is

(a) -7 (b) 7
(c) 73 (d) 106

81

GATE - 2003

The dimensional limits on a shaft of 25h7 are

(a) 25.000, 25.021 mm

(b) 25.000, 24.979 mm

(c) 25.000, 25.007 mm

(d) 25.000, 24.993 mm

82

GATE-2010 (PI)

A small bore is designated as 25H7. The lower (minimum) and upper (maximum) limits of the bore are 25.000 mm and 25.021 mm, respectively. When the bore is designated as 25H8, then the upper (maximum) limit is 25.033 mm. When the bore is designated as 25H6, then the upper (maximum) limit of the bore (in mm) is

(a) 25.001 (b) 25.005 (c) 25.009 (d) 25.013

83

GATE-2016 (PI)

The limits of a shaft designated as 100h5 are 100.000 mm and 100.014 mm. Similarly, the limits of a shaft designated as 100h8 are 100.000 mm and 100.055 mm. If a shaft is designated as 100h6, the fundamental deviation (in μm) for the same is

(a)-22 (b) zero (c) 22 (d) 24

84

Recommended Selection of Fits

TYPE OF FIT	SHAFT AND TOLERANCE	HOLE AND TOLERANCE H7	H8	H9	H11
CLEARANCE	c 11				■
	d 10			■	
	e 9			■	
	f 7		■		
	g 6	■			
	h 6	■			
TRANSITION	k 6	■			
	n 6	■			
INTERFERENCE	p 6	■			
	s 6	■			

85

GATE – 1996, IES-2012

The fit on a hole-shaft system is specified as H7-s6.The type of fit is

(a) Clearance fit

(b) Running fit (sliding fit)

(c) Push fit (transition fit)

(d) Force fit (interference fit)

86

IES - 2000

Which one of the following tolerances set on inner diameter and outer diameter respectively of headed jig bush for press fit is correct?

(a) G7 h 6 (b) F7 n6

(c) H 7h 6 (d) F7j6

87

For IES Only

Selective Assembly

- All the parts (hole & shaft) produced are measured and graded into a range of dimensions within the tolerance groups.
- Reduces the cost of production
- $\text{No. of group} = \dfrac{\text{Process capability}}{\text{Tolerance desired}}$

88

For IES Only

Interchangeability

- Interchangeability, a maintainability design factor, is quite closely related to standardization and is realized through standardization.
- If the variation of items are within certain limits, all parts of equivalent size will be equally fit for operating in machines and mechanisms and the mating parts will give the required fitting.
- This facilitates to select at random from a large number of parts for an assembly and results in a considerable saving in the cost of production, reduce assembly time, replacement and repair becomes very easy.

89

ISRO-2008

Interchangeability can be achieved by

(a) Standardization

(b) Better process planning

(c) Simplification

(d) Better product planning

90

IES 2010 Conventional

What is meant by interchangeable manufacture ?

IAS-2010 main

What are the differences between interchangeability and selective assembly ?

[4-Marks]

Tolerance Sink

- A design engineer keeps one section of the part blank (without tolerance) so that production engineer can dump all the tolerances on that section which becomes most inaccurate dimension of the part.
- Position of sink can be changing the reference point.
- Tolerance for the sink is the cumulative sum of all the tolerances and only like minded tolerances can be added i.e. either equally bilateral or equally unilateral.

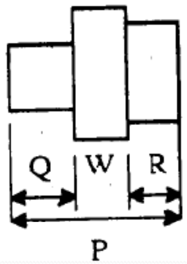
GATE - 2003

A part shown in the figure is machined to the sizes given below

$P = 35.00 \pm 0.08$ mm

$Q = 12.00 \pm 0.02$ mm

$R = 13.00^{+0.04}_{-0.02}$ mm

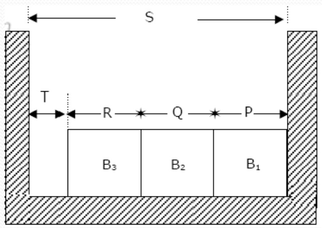


With 100% confidence, the resultant dimension W will have the specification

(a) 9.99 ± 0.03 mm
(b) 9.99 ± 0.13 mm
(c) 10.00 ± 0.03 mm
(d) 10.00 ± 0.13 mm

GATE - 1997

Three blocks B_1, B_2 and B_3 are to be inserted in a channel of width S maintaining a minimum gap of width T = 0.125 mm, as shown in Figure.



For P = 18. 75 ± 0.08;
Q = 25.00 ± 0.12;
R = 28.125 ± 0.1 and
S = 72.35 + X, (where all dimensions are in mm), the tolerance X is

(a) + 0.38 (b) - 0.38 (c) + 0.05 (d) -0.05

GATE-2015

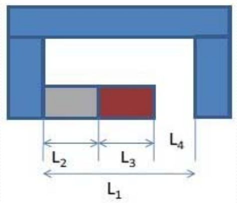
In the assembly shown below, the part dimensions are:

$L_1 = 22.0^{\pm 0.01}$ mm

$L_2 = L_3 = 10.0^{\pm 0.005}$ mm

Assuming normal distribution of part dimensions, the dimension L_4 in mm,

a) $2.00^{\pm 0.008}$ b) $2.00^{\pm 0.012}$
c) $2.00^{\pm 0.016}$ d) $2.00^{\pm 0.020}$



GATE – 2007 (PI)

Diameter of a hole after plating needs to be controlled between $30^{+0.050}_{+0.010}$ mm. If the plating thickness varies between 10 - 15 microns, diameter of the hole before plating should be

(a) $30^{+0.070}_{+0.030}$ mm (b) $30^{+0.065}_{+0.020}$ mm
(c) $30^{+0.080}_{+0.030}$ mm (d) $30^{+0.070}_{+0.040}$ mm

GATE-2013

Cylindrical pins of $25^{+0.020}_{+0.010}$ mm diameter are electroplated in a shop. Thickness of the plating is $30^{\pm 2.0}$ micron. Neglecting gage tolerances, the size of the GO gage in mm to inspect the plated components is

(a) 25.042 (b) 25.052 (c) 25.074 (d) 25.084

GATE - 2017

A cylindrical pin of $25^{+0.020}_{+0.010}$ mm diameter is electroplated. Plating thickness is $2^{\pm 0.005}$ mm. Neglecting the gauge tolerance, the diameter (in mm, up to 3 decimal points accuracy) of the GO ring gauge to inspect the plated pin is________

GATE - 2000

A slot is to be milled centrally on a block with a dimension of 40 ± 0.05 mm. A milling cutter of 20 mm width is located with reference to the side of the block within ± 0.02 mm. The maximum offset in mm between the centre lines of the slot and the block is

(a) ± 0.070 (b) 0.070

(c) ± 0.020 (d) 0.045

100

GATE - 2017

The standard deviation of linear dimensions P and Q are 3 μm and 4 μm, respectively. When assembled, the standard deviation (in μm) of the resulting linear dimension (P + Q) is________

101

Limit Gauges

- **Plug gauge:** used to check the holes. The GO plug gauge is the size of the low limit of the hole while the NOT GO plug gauge corresponds to the high limit of the hole.
- **Snap, Gap or Ring gauge**: used for gauging the shaft and male components. The Go snap gauge is of a size corresponding to the high (maximum) limit of the shaft, while the NOT GO gauge corresponds to the low (minimum limit).

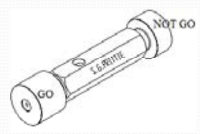


Fig. Plug gauge

Fig. Ring and snap gauges

102

ISRO-2008

Plug gauges are used to

(a) Measure the diameter of the workpieces

(b) Measure the diameter of the holes in the workpieces

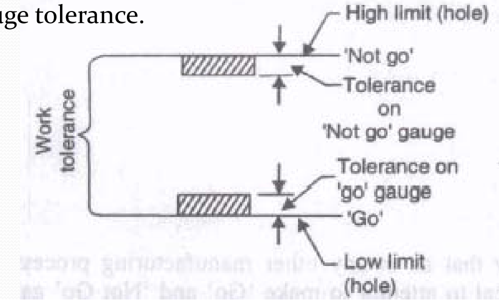
(c) Check the diameter of the holes in the workpieces

(d) Check the length of holes in the workpieces

103

Allocation of manufacturing tolerances

- **Unilateral system:** gauge tolerance zone lies entirely within the work tolerance zone.
- work tolerance zone becomes smaller by the sum of the gauge tolerance.



104

Example

Size of the hole to be checked 25 ± 0.02 mm

Here, Higher limit of hole = 25.02 mm

Lower limit of hole = 24.98 mm

Work tolerance = 0.04 mm

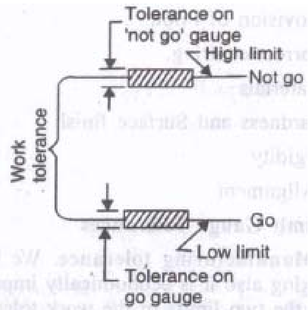
∴ Gauge tolerance = 10% of work tolerance = 0.004 mm

$$\therefore \text{Dimension of 'GO' Plug gauge} = 24.98^{+0.004}_{-0.000} \text{ mm}$$

$$\text{Dimension of 'NOT GO' Plug gauge} = 25.02^{+0.000}_{-0.004} \text{ mm}$$

105

- **Bilateral system:** in this system, the GO and NO GO gauge tolerance zones are bisected by the high and low limits of the work tolerance zone.



Taking example as above:

$$\therefore \text{Dimension of 'GO' Plug gauge} = 24.98^{+0.002}_{-0.002} \text{ mm}$$

$$\text{Dimension of 'NOT GO' Plug gauge} = 25.02^{+0.002}_{-0.002} \text{ mm}$$

106

- **Wear allowance:** GO gauges which constantly rub against the surface of the parts in the inspection are subjected to wear and loose their initial size.
- The size of go plug gauge is reduced while that of go snap gauge increases.
- To increase service life of gauges wear allowance is added to the go gauge in the direction opposite to wear. Wear allowance is usually taken as 5% of the work tolerance.
- Wear allowance is applied to a nominal diameter before gauge tolerance is applied.

107

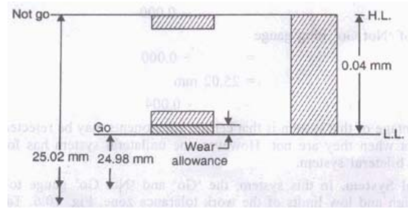
- Taking example of above:

∴ *Wear Allowance* = 5% of work tolerance = 0.002 mm

Nominal size of GO plug gauge = 24.98 + 0.002 mm

$$\therefore \text{Dimension of 'GO' Plug gauge} = 24.982^{+0.004}_{-0.000} \text{ mm}$$

$$\text{Dimension of 'NOT GO' Plug gauge} = 25.02^{+0.000}_{-0.004} \text{ mm}$$



108

GATE - 2014

A GO-NOGO plug gauge is to be designed for measuring a hole of nominal diameter 25 mm with a hole tolerance of ± 0.015 mm. Considering 10% of work tolerance to be the gauge tolerance and no wear condition, the dimension (in mm) of the GO plug gauge as per the unilateral tolerance system is

$(a)\, 24.985^{+0.003}_{-0.003}$ $(b)\, 25.015^{+0.000}_{-0.006}$

$(c)\, 24.985^{+0.03}_{-0.03}$ $(d)\, 24.985^{+0.003}_{-0.000}$

109

GATE - 2004

GO and NO-GO plug gages are to be designed for a hole $20^{0.05}_{0.01}$ mm. Gage tolerances can be taken as 10% of the hole tolerance. Following ISO system of gage design, sizes of GO and NO-GO gage will be respectively

(a) 20.010 mm and 20.050 mm
(b) 20.014 mm and 20.046 mm
(c) 20.006 mm and 20.054 mm
(d) 20.014 mm and 20.054 mm

110

GATE-2015

Which one of the following statements is TRUE?

a) The 'GO' gage controls the upper limit of a hole
b) The 'NO GO' gage controls the lower limit of a shaft
c) The 'GO' gage controls the lower limit of a hole
d) The 'NO GO' gage controls the upper limit of a hole

111

GATE - 1995

Checking the diameter of a hole using GO-NO-GO gauges is an, example of inspection by .....(variables/attributes)

The above statement is
(a) Variables
(b) Attributes
(c) Cant say
(d) Insufficient data

112

GATE – 2006, VS-2012

A ring gauge is used to measure

(a) Outside diameter but not roundness
(b) Roundness but not outside diameter
(c) Both outside diameter and roundness
(d) Only external threads

113

For IES Only

Taylor's Principle

This principle states that the GO gauge should always be so designed that it will cover the maximum metal condition (MMC) of as many dimensions as possible in the same limit gauges, whereas a NOT GO gauges to cover the minimum metal condition of one dimension only.

114

IES 2010 Conventional

Discuss a 'Go' gauge.

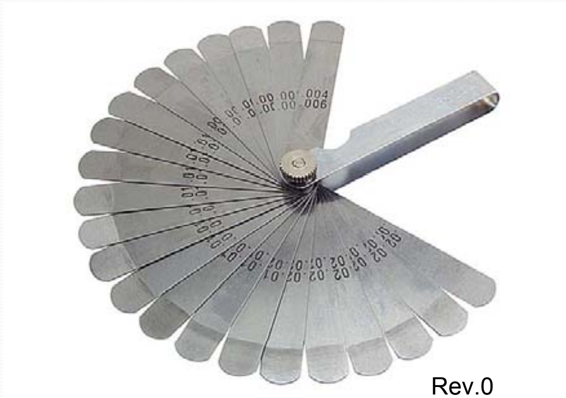
115

Limit Gauges

Gauge	For Measuring
Snap Gauge	External Dimensions
Plug Gauge	Internal Dimensions
Taper Plug Gauge	Taper hole
Ring Gauge	External Diameter
Gap Gauge	Gaps and Grooves
Radius Gauge	Gauging radius
Thread pitch Gauge	External Thread

116

Feeler Gauge



117

PSU

A feeler gauge is used to check the

(a) Pitch of the screw

(b) Surface roughness

(c) Thickness of clearance

(d) Flatness of a surface

118

GATE-2016

Match the following:

P. Feeler gauge	I. Radius of an object
Q. Fillet gauge	II. Diameter within limits by comparison
R. Snap gauge	III. Clearance or gap between components
S. Cylindrical plug gauge	IV. Inside diameter of straight hole

(a) P-III, Q-I, R-II, S-IV (b) P-III, Q-II, R-I, S-IV

(c) P-IV, Q-II, R-I, S-III (d) P-IV, Q-I, R-II, S-III

119

Why is a unilateral tolerance preferred over bilateral tolerance ?

- This system is preferred for Interchangeable manufacturing.
- It is easy and simple to determine deviations.
- It helps standardize the GO gauge end
- Helpful for operator because he has to machine the upper limit of the shaft and the lower limit of the hole knowing fully well that still some margin is left for machining before the part is rejected.

120

IES 2010(Conv) IAS-2014 (Main)

Why is a unilateral tolerance preferred over bilateral tolerance ?

121

For IES Only

Preferred Number

- A designed product needs standardization.
- Motor speed, engine power, machine tool speed and feed, all follows a definite pattern or series.
- This also helps in interchangeability of products.
- It has been observed that if the sizes are put in the form of geometric progression, then wide ranges are covered with a definite sequence.
- These numbers are called preferred numbers having common ratios as,
  $\sqrt[5]{10} \approx 1.58, \quad \sqrt[10]{10} \approx 1.26, \quad \sqrt[20]{10} \approx 1.12 \text{ and } \sqrt[40]{10} \simeq 1.06$
- Depending on the common ratio, four basic series are formed; these are R5 , R10 , R20 and R40

122

For IES Only

Preferred Number .....Contd.

- These are named as Renard series.
- Many other derived series are formed by multiplying or dividing the basic series by 10, 100 etc.
- Typical values of the common ratio for four basic G.P. series are given below.

$R5: \ 1.58 \ :1.0, 1.6, 2.5, \ldots\left(\sqrt[5]{10}, \sqrt[5]{100}, \sqrt[5]{1000}, \ldots.\right)$

$R10: \ 1.26 \ :1.0, 1.25, 1.6, \ldots\left(\sqrt[10]{10}, \sqrt[10]{100}, \sqrt[10]{1000}, \ldots.\right)$

$R20: \ 1.12 \ :1.0, 1.12, 1.4, \ldots\left(\sqrt[20]{10}, \sqrt[20]{100}, \sqrt[20]{1000}, \ldots.\right)$

$R40: \ 1.06 \ :1.0, 1.06, 1.12, \ldots\left(\sqrt[40]{10}, \sqrt[40]{100}, \sqrt[40]{1000}, \ldots.\right)$

123

IES-2013 conventional

Write the amount of allowance and tolerance that is permitted by the following classes of fit as per ANSI class 4 : Snug fit and class 7 :Medium force fit. Also mention applications.

124

American Standard Association Tolerance System

1. Heavy force shrunk fit
2. Medium force fit
3. Tight fit
4. Wringing fit
5. Snug fit
6. Medium fit
7. Free fit
8. Loose fit

125

Snug fit

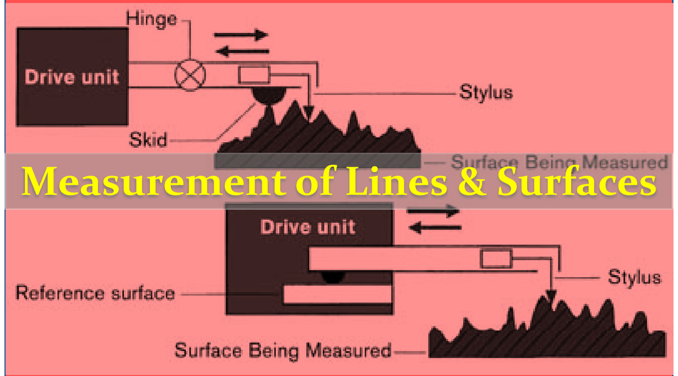
$\text{Tolerance} = 0.0004\text{D}^{1/3} \quad \textit{and} \text{ Deviation} = 0$

Medium force fit :

$\text{Tolerance} = 0.0006\text{D}^{1/3} \quad \textit{and} \text{ Deviation} = 0.0005D - 0.0006D^{1/3}$

- Snug fit is applicable where no shake is permissible
- Medium force fit is applicable for shrink fit on cast iron

126



Measurement of Lines & Surfaces

By S K Mondal

Accuracy & Precision

- **Accuracy** - The ability of a measurement to match the actual (true) value of the quantity being measured. The expected ability for a system to discriminate between two settings. Smaller the bias more accurate the data.
- **Precision** - The precision of an instrument indicates its ability to reproduce a certain reading with a given accuracy 'OR' it is the degree of agreement between repeated results.
- Precision data have small dispersion (spread or scatter) but may be far from the true value.
- A measurement can be accurate but not precise, precise but not accurate, neither, or both.
- A measurement system is called valid if it is both accurate and precise.

128

129

GATE-2017 (PI)

Accuracy of a measuring instrument is expressed as

(a) true value – measured value

(b) measured value - true value

(c) $1-\left|\dfrac{\text{true value-measured value}}{\text{true value}}\right|$

(d) $1+\left|\dfrac{\text{true value-measured value}}{\text{true value}}\right|$

130

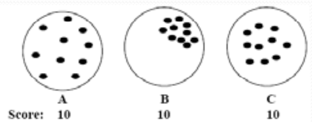
Repeatability

- It is the ability of a measuring system to reproduce output readings when the same input is applied to it consecutively, under the same conditions, and in the same direction.
- Imperfections in mechanical systems can mean that during a Mechanical cycle, a process does not stop at the same location, or move through the same spot each time. The variation range is referred to as repeatability.

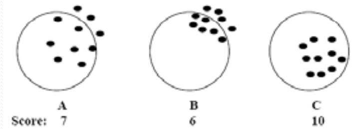
131

Reliability of measurement

- **It is a quantitative characteristic which implies confidence in the measured results depending on whether or not the frequency distribution characteristics of their deviations from the true values of the corresponding quantities are known. It is the probability that the results will be predicted.**



Which of these targets represents accurate shooting? Precise shooting? Reliable shooting?



A change in one variable, such as wind, alters the results as shown. Dose this show which shooting was the most reliable?

132

Calibration

- It is the setting or correcting of a measuring device usually by adjusting it to match or conform to a dependably known value or act of checking.
- Calibration determines the performance characteristics of an instrument, system or reference material. It is usually achieved by means of a direct comparison against measurement standards or certified reference materials.
- It is very widely used in industries.
- A calibration certificate is issued and, mostly, a sticker is provided for the instrument.

133

- **Drift:** It is a slow change of a metrological characteristics of a measuring instruments
- **Resolution:** It is the smallest change of the measured quantity which changes the indication of a measuring instruments
- **Sensitivity:** The smallest change in the value of the measured variable to which the instrument respond is sensitivity. It denotes the maximum changes in an input signal that will not initiate a response on the output.
- **Rule of 10 or Ten-to one rule:** That the discrimination (resolutions) of the measuring instrument should divide the tolerance of the characteristic to be measured into ten parts. In other words, the gauge or measuring instrument should be 10 times as accurate as the characteristic to be measured.

134

Errors

- **Systematic errors or fixed errors (Bias):** Due to faulty or improperly calibrated instruments. These may be reduced or eliminated by correct choice of instruments.

  Eg. calibration errors, Errors of technique etc.
- **Random errors:** Random errors are due to non-specific cause like natural disturbances that may occur during the experiment. These cannot be eliminated.

  Eg. Errors stemming from environmental variations, Due to Insufficient sensitivity of measuring system

135

Linear measurements

Some of the instruments used for the linear measurements are:

- Rules (Scale)
- Vernier
- Micrometer (Most widely used, Working Standard)
- Height gauge
- Bore gauge
- Dial indicator
- Slip gauges or gauge blocks (Most accurate, End Standard)

136

Vernier Caliper

- A vernier scale is an auxiliary scale that slides along the main scale.
- The vernier scale is that a certain number n of divisions on the vernier scale is equal in length to a different number (usually one less) of main-scale divisions.

$$nV = (n - 1)S$$

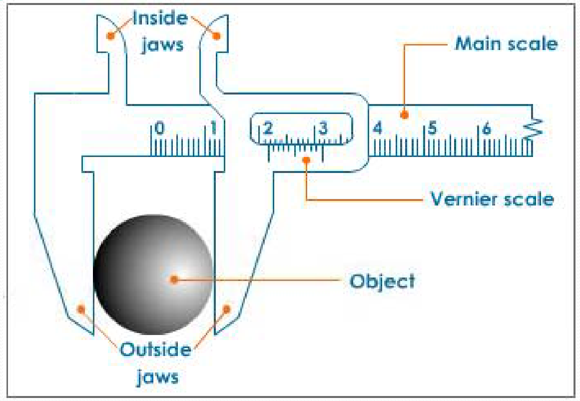
where n = number of divisions on the vernier scale

V = The length of one division on the vernier scale

and S = Length of the smallest main-scale division

- Least count is applied to the smallest value that can be read directly by use of a vernier scale.
- Least count = $S - V = \frac{1}{n}S$

137



Vernier Caliper

138

ISRO-2010

The vernier reading should not be taken at its face value before an actual check has been taken for

(a) Zero error

(b) Its calibration

(c) Flatness of measuring jaws

(d) Temperature equalization

139

ISRO-2008

The least count of a metric vernier caliper having 25 divisions on vernier scale, matching with 24 divisions of main scale (1 main scale divisions = 0.5 mm) is

(a) 0.005 mm (b) 0.01 mm

(c) 0.02 mm (d) 0.005mm

140

Metric Micrometer

- A *micrometer* allows a measurement of the size of a body. It is one of the most accurate mechanical devices in common use.
- It consists a main scale and a thimble

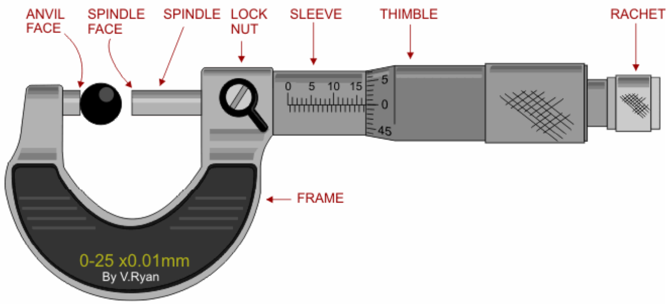
Method of Measurement

Step-I: Find the whole number of mm in the barrel

Step-I: Find the reading of barrel and multiply by 0.01

Step-III: Add the value in Step-I and Step-II

141



Micrometer

142

ISRO-2009, 2011

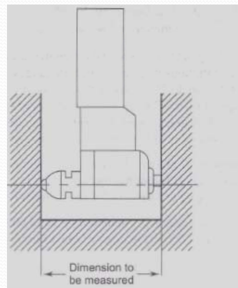
In a simple micrometer with screw pitch 0.5 mm and divisions on thimble 50, the reading corresponding to 5 divisions on barrel and 12 divisions on thimble is

(a) 2.620 mm (b) 2.512 mm

(c) 2.120 mm (d) 5.012 mm

143

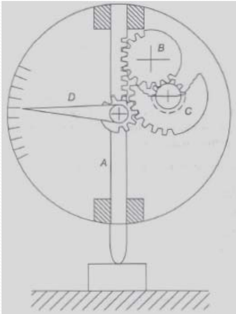
- **Bore Gauge:** used for measuring bores of different sizes ranging from small-to-large sizes.
- Provided with various extension arms that can be added for different sizes.



Bore gauge measuring an inside dimensi

144

- **Dial indicator:** Converts a linear displacement into a radial movement to measure over a small range of movement for the plunger.
- The typical least count that can be obtained with suitable gearing dial indicators is 0.01 mm to 0.001 mm.
- It is possible to use the dial indicator as a comparator by mounting it on a stand at any suitable height.



Principle of a dial indicator

145

Applications of dial indicator include:

- centering workpices to machine tool spindles
- offsetting lathe tail stocks
- aligning a vice on a milling machine
- checking dimensions

146

GATE – 2008 S-1

A displacement sensor (a dial indicator) measures the lateral displacement of a mandrel mounted on the taper hole inside a drill spindle. The mandrel axis is an extension of the drill spindle taper hole axis and the protruding portion of the mandrel surface is perfectly cylindrical. Measurements are taken with the sensor placed at two positions P and Q as shown in the figure. The readings are recorded as R_x = maximum deflection minus minimum deflection, corresponding to sensor position at X, over one rotation.

147

GATE – 2008 contd... from S-2

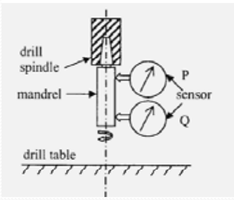
If $R_P = R_Q > 0$, which one of the following would be consistent with the observation?

(A) The drill spindle rotational axis is coincident with the drill spindle taper hole axis

(B) The drill spindle rotational axis intersects the drill spindle taper hole axis at point P

(C) The drill spindle rotational axis is parallel to the drill spindle taper hole axis

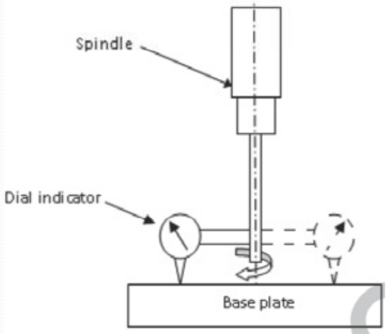
(D) The drill spindle rotational axis intersects the drill spindle taper hole axis at point Q



148

GATE – 2014(PI) S-1

The alignment test "Spindle square with base plate" is applied to the radial drilling machine. A dial indicator is fixed to the cylindrical spindle and the spindle is rotated to make the indicator touch the base plate at different points



149

GATE – 2014(PI) S-2

This test inspects whether the

(a) spindle vertical feed axis is perpendicular to the base plate

(b) axis of symmetry of the cylindrical spindle is perpendicular to the base plate

(c) axis of symmetry, the rotational axis and the vertical feed axis of the spindle are all coincident

(d) spindle rotational axis is perpendicular to the base plate

150

Slip Gauges or Gauge blocks

- These are small blocks of alloy steel.
- Used in the manufacturing shops as length standards.
- Not to be used for regular and continuous measurement.
- Rectangular blocks with thickness representing the dimension of the block. The cross-section of the block is usually 32 mm x 9 mm.
- Are hardened and finished to size. The measuring surfaces of the gauge blocks are finished to a very high degree of finish, flatness and accuracy.

151

- Come in sets with different number of pieces in a given set to suit the requirements of measurements.
- A typical set consisting of 88 pieces for metric units is shown in.
- To build any given dimension, it is necessary to identify a set of blocks, which are to be put together.
- Number of blocks used should always be the smallest.
- Generally the top and bottom Slip Gauges in the pile are 2 mm wear gauges. This is so that they will be the only ones that will wear down, and it is much cheaper to replace two gauges than a whole set.

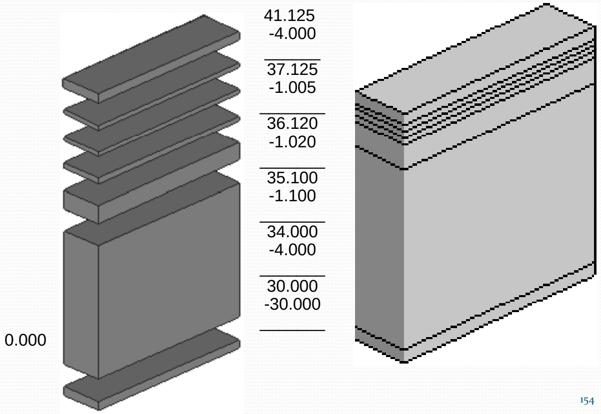
152

To make up a Slip Gauge pile to 41.125 mm

- A Slip Gauge pile is set up with the use of simple maths.
- Decide what height you want to set up, in this case 41.125mm.
- Take away the thickness of the two wear gauges, and then use the gauges in the set to remove each place of decimal in turn, starting with the lowest.

153

To make up a Slip Gauge pile to 41.125 mm



154

155

A Metric slip gauge set (88 Pieces)

Slip gauges size or range, mm	Increment, mm	Number of Pieces
1.005	-	1
1.001 to 1.009	0.001	9
1.010 to 1.490	0.010	49
0.500 to 9.500	0.500	19
10 to 100	10.000	10

156

ISRO-2010

A master gauge is

(a) A new gauge

(b) An international reference standard

(c) A standard gauge for checking accuracy of gauges used on shop floors

(d) A gauge used by experienced technicians

157

ISRO-2008

Standards to be used for reference purposes in laboratories and workshops are termed as

(a) Primary standards

(b) Secondary standards

(c) Tertiary standards

(d) Working standards

158

Comparators

- Comparator is another form of linear measuring method, which is quick and more convenient for checking large number of identical dimensions.
- During the measurement, a comparator is able to give the deviation of the dimension from the set dimension.
- Cannot measure absolute dimension but can only compare two dimensions.
- Highly reliable.
- To magnify the deviation, a number of principles are used such as mechanical, optical, pneumatic and electrical.

159

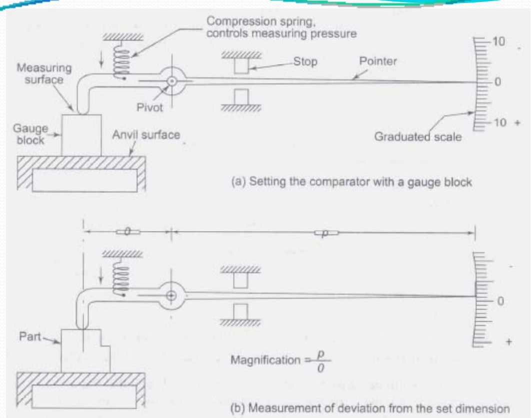


Fig. Principle of a comparator

160

GATE – 2007 (PI)

Which one of the following instruments is a comparator ?

(a) Tool Maker's Microscope

(b) GO/NO GO gauge

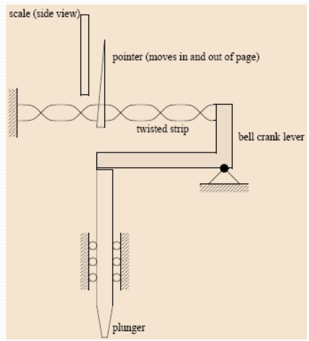
(c) Optical Interferometer

(d) Dial Gauge

161

Mechanical Comparators

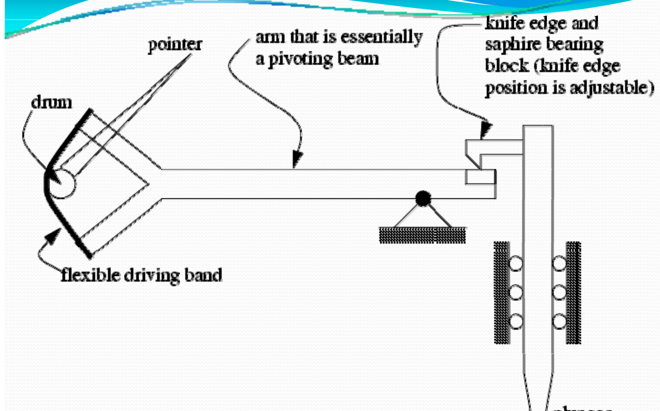
- The **Mikrokator** principle greatly magnifies any deviation in size so that even small deviations produce large deflections of the pointer over the scale.



162

Sigma Mechanical Comparator

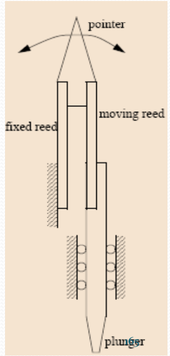
The Sigma Mechanical Comparator uses a partially wrapped band wrapped about a driving drum to turn a pointer needle. The assembly provides a frictionless movement with a resistant pressure provided by the springs.



Sigma Mechanical Comparator

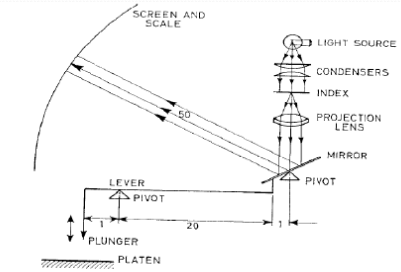
Mechanical Comparators

- The Eden-Rolt Reed system uses a pointer attached to the end of two reeds. One reed is pushed by a plunger, while the other is fixed. As one reed moves relative to the other, the pointer that they are commonly attached to will deflect.



Optical Comparators

- These devices use a plunger to rotate a mirror. A light beam is reflected off that mirror, and simply by the virtue of distance, the small rotation of the mirror can be converted to a significant translation with little friction.



In this system, Mechanical amplification = 20 /1 , And, Optical amplification 50 /1 x 2

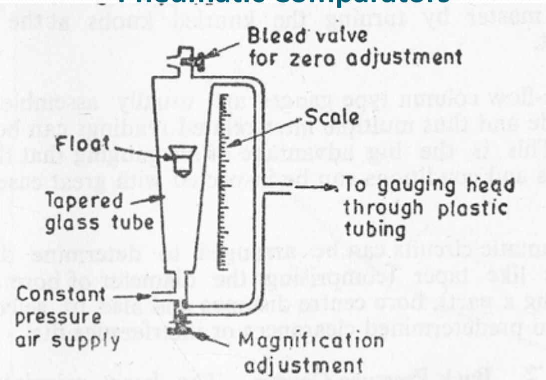
It is multiplied by 2, because if mirror is tilted by an angle δθ, then image will be tilted by 2 x δθ. Thus overall magnification of this system

= 2 x (20/1) (50/1 =2000 units)

Pneumatic Comparators

- Flow type:
  - The float height is essentially proportional to the air that escapes from the gauge head
  - Master gauges are used to find calibration points on the scales
  - The input pressure is regulated to allow magnification adjustment

Pneumatic Comparators



IFS-2015

Define a comparator.

Write at least six desirable features it should possess.

Also name four types of comparators.

[8 Marks]

Angular Measurement

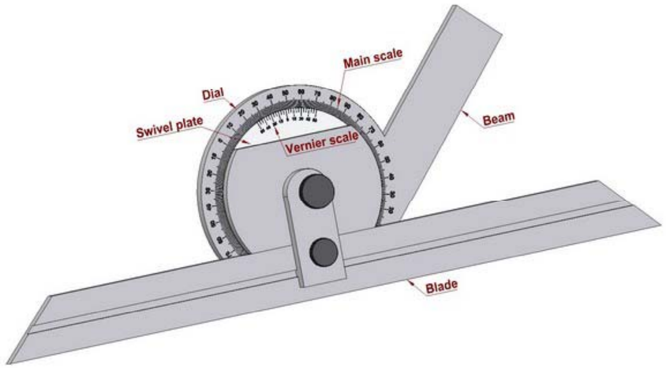
This involves the measurement of angles of tapers and similar surfaces. The most common angular measuring tools are:

- Bevel protractor
- Sine bar

Bevel Protractor

- Is part of the machinist's combination square.
- The flat base of the protractor helps in setting it firmly on the workpiece and then by rotating the rule, it is possible to measure the angle. It will typically have a discrimination of one degree.

172



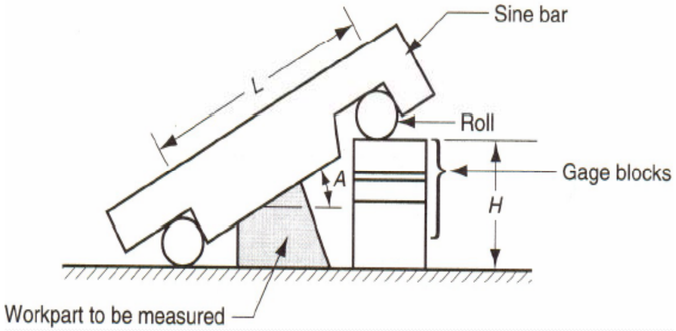
A Bevel Protractor

173

Sine Bar

- When a reference for a non-square angle is required, a sine bar can be used.
- Basically a sine bar is a bar of known length. When gauge blocks are placed under one end, the sine bar will tilt to a specific angle.
- Knowing the height differential of the two rollers in alignment with the workpiece ,the angle can be calculated using the sine formula.
- A sine bar is specified by the distance between the centre of the two rollers, i.e. 100 mm, 200 mm, & 300 mm. the various part of sine bar are hardened before grinding & lapping.

174



$$\sin\theta = \frac{H}{L}$$

175

ISRO-2011

A sine bar is specified by

(a) Its total length

(b) The size of the rollers

(c) The centre distance between the two rollers

(d) The distance between rollers and upper surface

176

GATE -2012 (PI)

A sine bar has a length of 250 mm. Each roller has a diameter of 20 mm. During taper angle measurement of a component, the height from the surface plate to the centre of a roller is 100 mm.

The calculated taper angle (in degrees) is

(a) 21.1 (b) 22.8 (c) 23.6 (d) 68.9

177

GATE-2018

The height (in mm) for a 125 mm sine bar to measure a taper of 27°32' on a flat work piece is__________(correct to three decimal places).

178

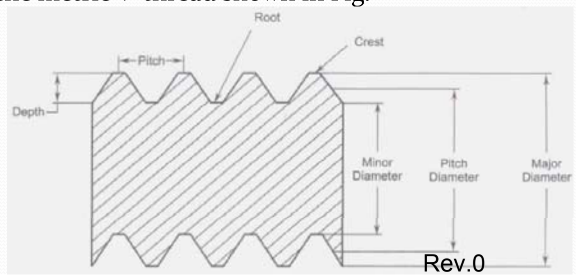
Dis-advantages

- 1. Sine bars cannot be used for conveniently for measuring angles more than 60° because of slip gauge adjustment problems.
- 2. Misalignment of workpiece with sine bar may sometimes introduce considerable errors.

179

Thread Measurements

- Threads are normally specified by the major diameter.
- Though there are a large variety of threads used in engineering, the most common thread encountered is the metric V-thread shown in Fig.



180

- The parameters that are normally measured are:
- Major diameter
  - Micrometer
- Pitch diameter
  - Floating Carriage micrometer
  - Wire method (Three wire and two wire)
- Pitch
  - Screw pitch gauge
  - Pitch measuring machine
- Thread form
  - Optical projector

181

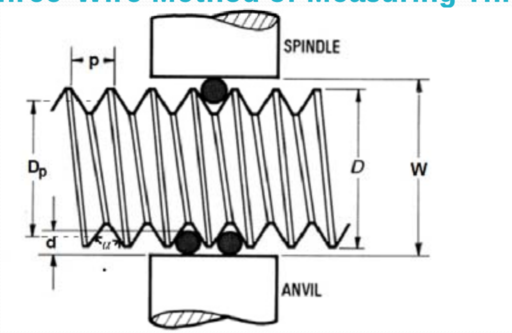
Three-Wire Method

- Three wires of equal diameter placed in thread, two on one side and one on other side
- Standard micrometer used to measure distance over wires (M)
- Different sizes and pitches of threads require different sizes of wires

182

183

The Three-Wire Method of Measuring Threads



D_p = pitch diameter or Effective diameter

p = pitch of thread, and α = thread angle

184

- **Distance W over the outer edge**

$$W = D_p + d\left(1 + \text{cosec}\frac{\alpha}{2}\right) - \frac{p}{2}\cot\frac{\alpha}{2}$$

For ISO metric thread, $\alpha = 60$ and $D_p = D - 0.6496p$

$$W = D + 3d - 1.5156p$$

- **Best wire size**

$$d = \frac{p}{2}\sec\frac{\alpha}{2}$$

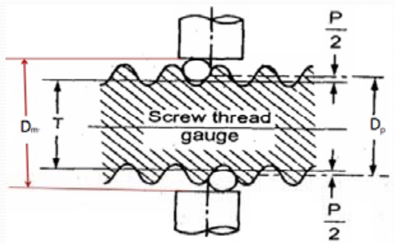
For ISO metric thread, $\alpha = 60$

$$d = 0.5774p$$

185

Two-Wire Method

- Two wires of equal diameter placed in thread, two on one side and one on other side



186

- **Pitch Diameter or Effective Dia.**

$$D_p = T + P$$

$$= T + \frac{p}{2}\cot\left(\frac{\alpha}{2}\right) - d\left(\text{cosec}\frac{\alpha}{2} - 1\right)$$

T = Dimensions under the wire = $D + (D_m - D_s)$

D = Diameter of master or standard cylinder

D_m = Micrometer reading over standard cylinder with two wire

D_s = Micrometer reading over the plug screw gauge with the wire

P = Pitch value

- **Best wire size**

$$d = \frac{p}{2}\sec\frac{\alpha}{2}$$

187

GATE – 2011 (PI)

The best wire size (in mm) for measuring effective diameter of a metric thread (included angle is 60°) of 20 mm diameter and 2.5 mm pitch using two wire method is

(a) 1.443
(b) 0.723
(c) 2.886
(d) 2.086

188

GATE-2013

A metric thread of pitch 2 mm and thread angle 60 inspected for its pitch diameter using 3-wire method. The diameter of the best size wire in mm is

(a) 0.866 (b) 1.000 (c) 1.154 (d) 2.000

189

IES-2017 (Pre)

A metric thread of pitch 2 mm and thread angle 60° is inspected for its pitch diameter using the 3-wire method. The indicated diameter of the wire will be nearly

(a) 0.85 mm (b) 1.05 mm

(c) 1.15 mm (d) 2.05 mm

GATE – 2011 (PI)

To measure the effective diameter of an external metric thread (included angle is 60°) of 3.5 mm pitch, a cylindrical standard of 30.5 mm diameter and two wires of 2 mm diameter each are used. The micrometer readings over the standard and over the wires are 16.532 mm and 15.398 mm, respectively. The effective diameter (in mm) of the thread is

(a) 33.366 (b) 30.397

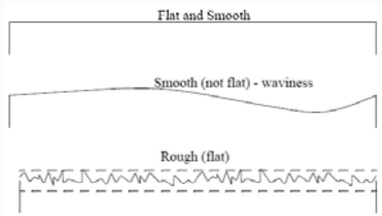
(c) 29.366 (d) 26.397

Measurement of Surfaces

Surfaces

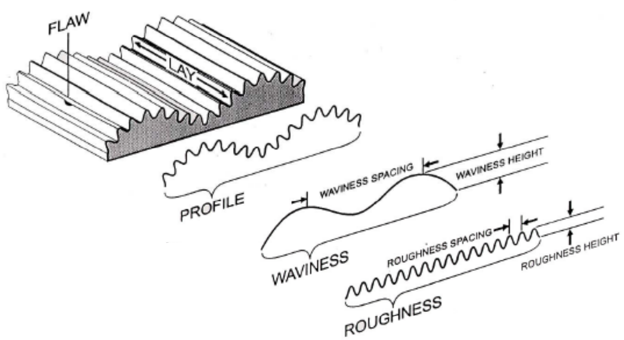
- No surface is perfectly smooth, but the better the surface quality, the longer a product generally lasts, and the better is performs.
- Surface texture can be difficult to analyse quantitatively.
- Two surfaces may be entirely different, yet still provide the same CLA (Ra) value.

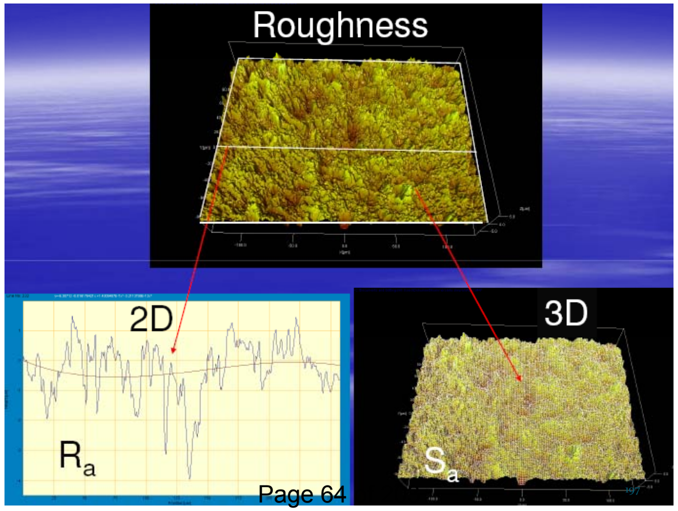
- Surface geometry can be quantified a few different ways.



- Real surfaces are rarely so flat, or smooth, but most commonly a combination of the two.

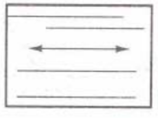
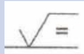
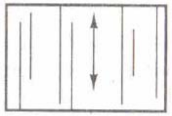
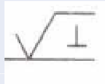
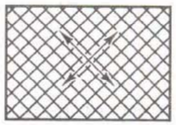
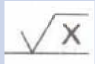
- **Roughness height:** is the parameter with which generally the surface finish is indicated. It is specified either as arithmetic average value or the root mean square value.
- **Roughness width:** is the distance parallel to the nominal part surface within which the peaks and valleys, which constitutes the predominant pattern of the roughness.
- **Roughness width cut-off:** is the maximum width of the surface that is included in the calculation of the roughness height.





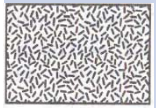
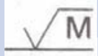
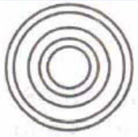
- **Waviness:** refers to those surface irregularities that have a greater spacing than that of roughness width.
  - Determined by the height of the waviness and its width.
  - The greater the width, the smoother is the surface and thus is more desirable.
- **Lay direction:** is the direction of the predominant surface pattern produced on the workpiece by the tool marks.
- **Flaw:** are surface irregularities that are present which are random and therefore will not be considered.

Lay

Diagram	Symbol	Description
		**Parallel lay:** Lay parallel to the Surface. Surface is produced by shaping, planning etc.
		**Perpendicular lay:** Lay perpendicular to the Surface. Surface is produced by shaping and planning
		**Crossed lay:** Lay angular in both directions. Surface is produced by knurling, honing.

199

Lay Contd..

Diagram	Symbol	Description
		**Multidirectional lay:** Lay multidirectional. Surface is produced by grinding, lapping, super finishing.
		**Circular lay:** Approximately circular relative to the center. Surface is produced by facing.
		**Radial lay:** Approximately radial relative to the center of the nominal surface.

200

IES-2012

In connection with surface texture define

(a) waviness

(b) flaws, and

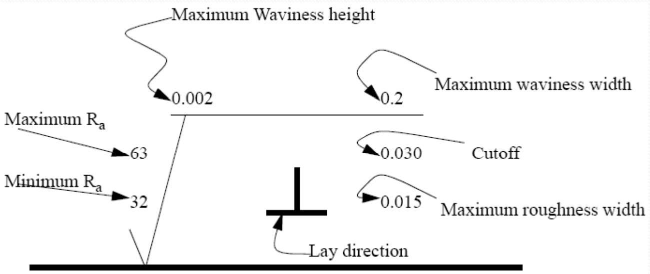
(c) lay.

List three defects found on surfaces.

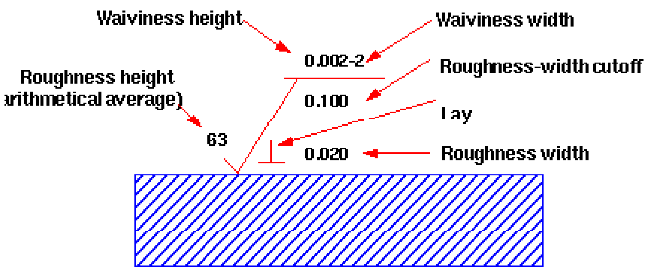
[2 marks]

201

Representation of Surface Roughness



202

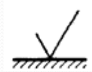


203

INDICATION OF SURFACE TEXTURE

The **basic symbol** consists of two legs of **unequal** length inclined at approximately **60'** to the line representing the considered surface

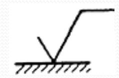
The symbol must be represented by thin line



If the removal of material by **machining** is required, a bar is added to the basic symbol,

If the **removal of material is not permitted**, a circle is added to the basic symbol.

When **special surface characteristics** have to be indicated, a line is added to the longer arm of any of the above symbols,



Basic symbol : only be used alone when its meaning is explained by a note

204

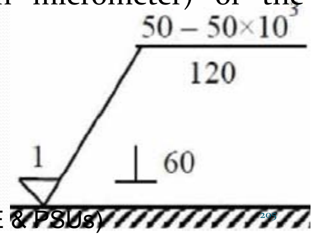
GATE-2017 (PI)

A machined surface with standard symbols indicating the surface texture is shown in the Figure. (All dimensions in the Figure are in micrometer).

The waviness height (in micrometer) of the surface is

(a) 1 (b) 50

(c) 60 (d) 120

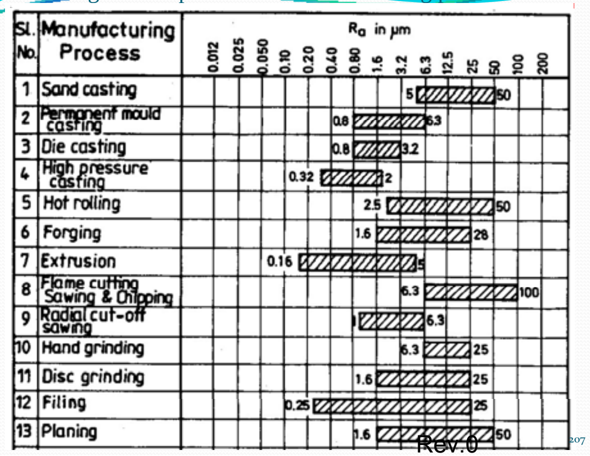


205

Roughness R_a (μm)	Roughness Grade Number	Roughness Symbol
50	N12	-
25	N11	∇
12.5	N10	
6.3	N9	∇ ∇
3.2	N8	
1.6	N7	
0.8	N6	∇ ∇ ∇
0.4	N5	
0.2	N4	
0.1	N3	∇ ∇ ∇ ∇
0.05	N2	
0.025	N1	

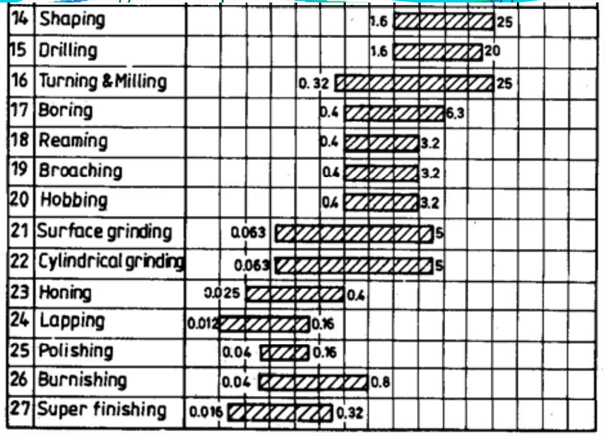
206

Surface Roughness expected from manufacturing processes



207

Surface Roughness expected from manufacturing processes



IES-2016 conventional

Show in a figure location of the surface texture details when used with machining symbols.

[4 Marks]

IES - 1992

Which grade symbol represents surface rough of broaching?

(a) N_{12} (b) N_8
(c) N_4 (d) N_1

- **Waviness height** - the distance from a peak to a valley
- **Waviness width** - the distance between peaks or valleys
- **Roughness width cutoff** - a value greater than the maximum roughness width that is the largest separation of surface irregularities included in the measurements. Typical values are (0.003", 0.010", 0.030", 0.100", 0.300")
- **Lay** - the direction the roughness pattern should follow
  - Stylus travel is perpendicular to the lay specified.

IFS-2011

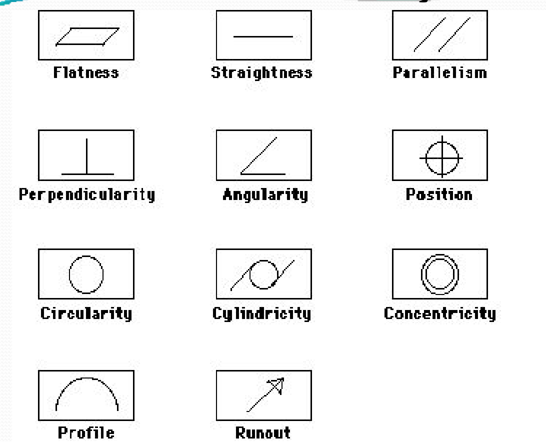
What is meant by interchangeable manufacture?

Laser light has unique advantages for inspection.

What are they ? Define the terms 'roughness height', 'waviness width' and 'lay' in connection with surface irregularities.

[10-marks]

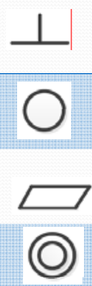
Geometric Tolerance symbol



GATE-2018 (PI)

Match the geometric tolerances with their correct symbols:

P. Flatness	1.	
Q. Perpendicularity	2.	
R. Concentricity	3.	
S. Roundness (Circularity)	4.	



(a) P – 1, Q – 3, R – 4, S – 2 (b) P – 3, Q – 1, R – 4, S – 2
(c) P – 3, Q – 1, R – 2, S – 4 (ds) P – 3, Q – 2, R – 1, S – 4

GATE -2007(PI)

The geometric tolerance that does NOT need a datum for its specification is

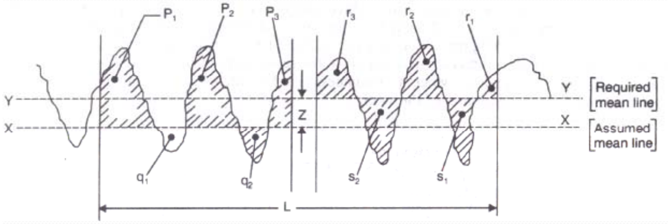
(a) Concentricity (b) Runout
(c) Perpendicularity (d) Flatness

Evaluation of Surface Roughness

1. Centre line average (CLA) or arithmetic mean deviation denoted as R_a.
2. Root mean square value (R_g) : rms value
3. Maximum peak to valley roughness (h_{max})
4. The average of the five highest peak and five deepst valleys in the sample.
5. The average or leveling depth of the profile.

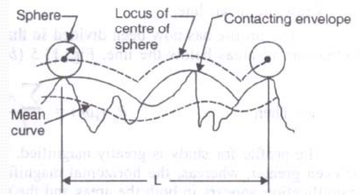
Determination of Mean Line

- **M-System:** After plotting the characteristic of any surface a horizontal line is drawn by joining two points. This line is shifts up and down in such a way that 50% area is above the line and 50% area is below the line



Determination of Mean Line

- **E-System: (Envelop System)** A sphere of 25 mm diameter is rolled over the surface and the locus of its centre is being traced out called envelope. This envelope is shifted in downward direction till the area above the line is equal to the area below the line. This is called mean envelope and the system of datum is called E-system.



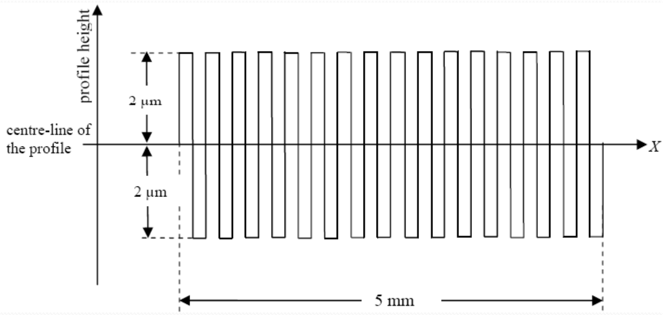
Arithmetical Average:

- Measured for a specified area and the figures are added together and the total is then divided by the number of measurements taken to obtain the mean or arithmetical average (AA).
- It is also sometimes called the centre line average or CLA value. This in equation form is given by

$$R_a = \frac{1}{L}\int_0^L |y(x)|\,dx \cong \frac{1}{N}\sum |y_i|$$

GATE-2016 (PI)

The roughness profile of a surface is depicted below.



The surface roughness parameter Ra (in µm) is ________

- The other parameter that is used sometimes is the root mean square value of the deviation in place of the arithmetic average , This in expression form is

$$R_{RMS} = \sqrt{\frac{1}{N}\sum y_i^2}$$

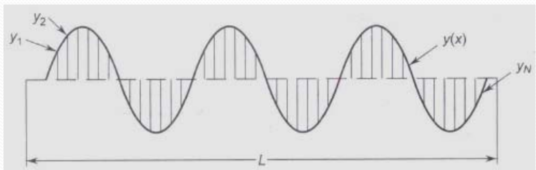


Fig. Surface roughness parameters

ISRO-2011

CLA value and RMS values are used for measurement of

(a) Metal hardness

(b) Sharpness of tool edge

(c) Surface dimensions

(d) Surface roughness

IES - 2006

The M and E-system in metrology are related to measurement of:

(a) Screw threads (b) Flatness

(c) Angularity (d) Surface finish

IES - 2007

What is the dominant direction of the tool marks or scratches in a surface texture having a directional quality, called?

(a) Primary texture (b) Secondary texture

(c) Lay (d) Flaw

IES - 2008

What term is used to designate the direction of the predominant surface pattern produced by machining operation?

(a) Roughness (b) Lay

(c) Waviness (d) Cut off

IES 2010

Match List I with List II and select the correct answer using the code given below the lists:

List I (Symbols for direction of lay)

A. =

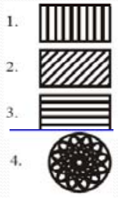
B. ×

C. I

D. R

List II (Surface texture)

1.
2.
3.
4.



	A	B	C	D		A	B	C	D
(a)	4	2	1	3	(b)	3	2	1	4
(c)	4	1	2	3	(d)	3	1	2	4

226

IES - 2008

What symbol is used to indicate surface roughness?

(a) = (b) $\sqrt{}$

(c) $^{0.1}\sqrt{}$ (d) Δ

227

ISRO-2010

Surface roughness on a drawing is represented by

(a) Triangles

(b) Circles

(c) Squares

(d) Rectangles

228

IAS – 2013 Main

For a machined surface, show macro- and micro-irregularities. What are their causes?

What are the various measures of surface finish? Explain any three of them.

229

Methods of measuring Surface Roughness

There are a number of useful techniques for measuring surface roughness:

- **Observation and touch** - the human finger is very perceptive to surface roughness
- **stylus based equipment** - very common
- **Interferometry** - uses light wave interference patterns (discussed later)

230

Observation Methods

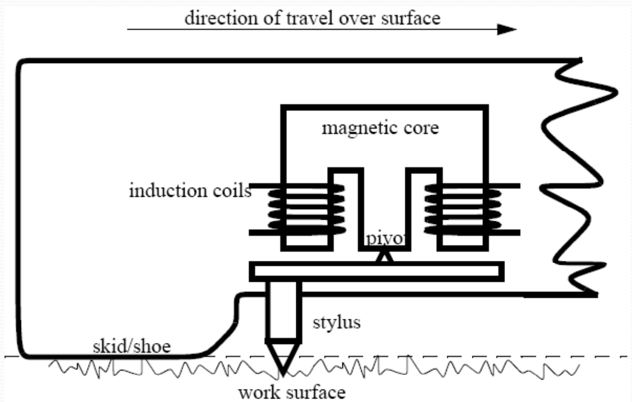
- Human perception is highly relative.
- To give the human tester a reference for what they are touching, commercial sets of standards are available.
- Comparison should be made against matched identical processes.
- One method of note is the finger nail assessment of roughness and touch method.

231

Stylus Equipment

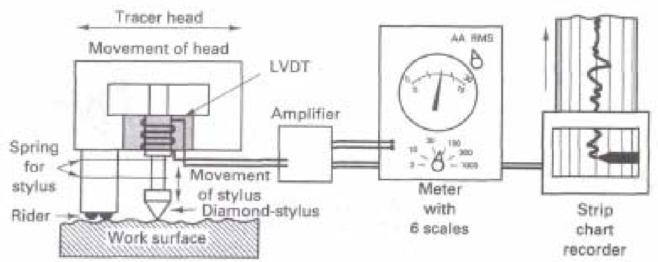
- Uses a stylus that tracks small changes in surface height, and a skid that follows large changes in surface height.
- The relative motion between the skid and the stylus is measured with a magnetic circuit and induction coils.
- One example of this is the Brown & Sharpe Surfcom unit.

232



233

Schematic of stylus profile device for measuring surface roughness and surface profile with two readout devices shown: a meter for AA or rms values and a strip-chart recorder for surface profile.



234

Profilometer

- Measuring instrument used to measure a surface's profile, in order to quantify its roughness.
- Vertical resolution is usually in the nanometre level, though lateral resolution is usually poorer.

Contact profilometers

- A diamond stylus is moved vertically in contact with a sample and then moved laterally across the sample for a specified distance and specified contact force.
- A profilometer can measure small surface variations in vertical stylus displacement as a function of position.
- The radius of diamond stylus ranges from 20 nanometres to 25 μm.

Non-contact Profilometers

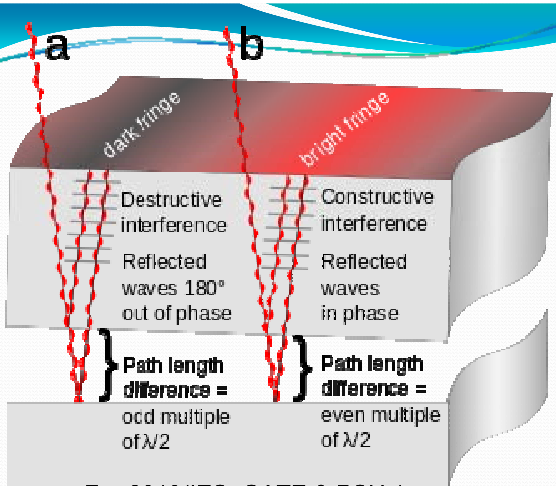
- An optical profilometer is a non-contact method for providing much of the same information as a stylus based profilometer.
- There are many different techniques which are currently being employed, such as laser triangulation (triangulation sensor), confocal microscopy and digital holography.

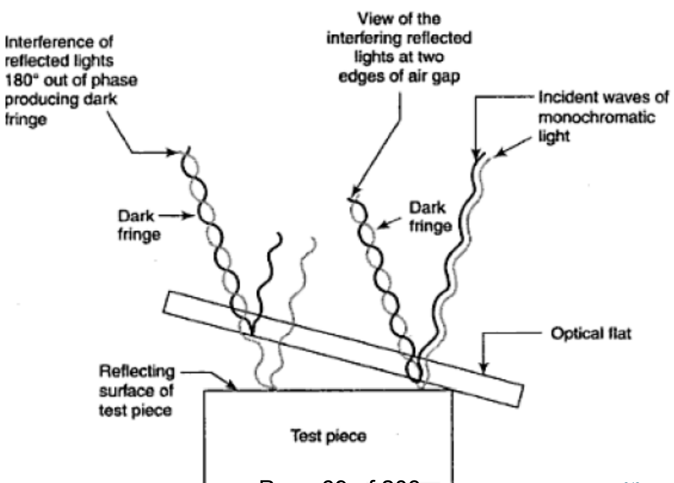
Advantages of optical Profilometers

- Because the non-contact profilometer does not touch the surface the scan speeds are dictated by the light reflected from the surface and the speed of the acquisition electronics.
- Optical profilometers do not touch the surface and therefore cannot be damaged by surface wear or careless operators.

Optical Flats

- Optical-grade clear fused quartz or glass structures lapped and polished to be extremely flat on one or both sides.
- Used with a monochromatic light to determine the flatness of other optical surfaces by interference.
- When a flat surface of another optic is placed on the optical flat, interference fringes are seen due to interference in the tiny gap between the two surfaces.
- The spacing between the fringes is smaller where the gap is changing more rapidly, indicating a departure from flatness in one of the two surfaces, in a similar way to the contour lines on a map.





GATE-2018 (PI)

Which one of the following instruments makes use of the principle of interference of light?

(a) Optical flat

(b) Auto-collimator

(c) Optical projector

(d) Coordinate measuring machine

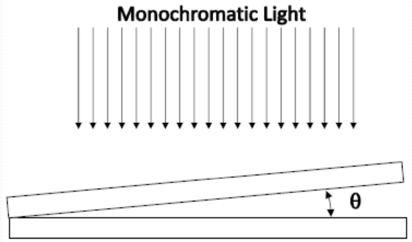
- When the fringes are perfectly straight and same fringe width for dark and bright band we conclude that the surface is perfectly flat.
- For convex surface the fringes curve around the point of contact.
- For concave surface the fringes curve away from the point of contact.

The distance of air gap between two successive fringes is given by $= \frac{\lambda}{2}$

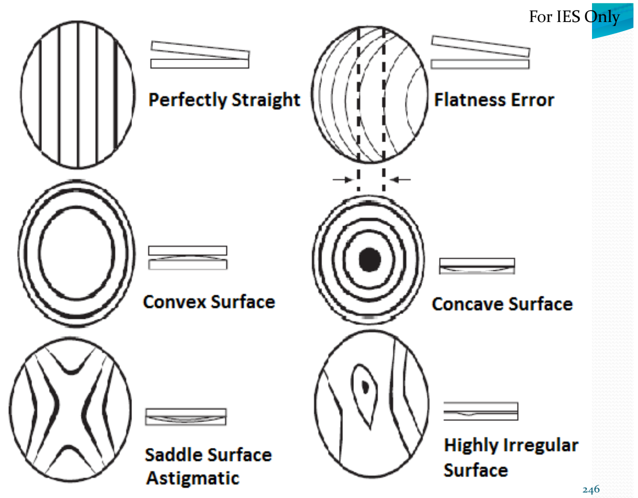
Distance of air gap of interference fringe of n^{th} order is $= \frac{n\lambda}{2}$

GATE-2016

Two optically flat plates of glass are kept at a small angle θ as shown in the figure. Monochromatic light is incident vertically.



If the wavelength of light used to get a fringe spacing of 1 mm is 450 nm, the wavelength of light (in nm) to get a fringe spacing of 1.5 mm is ________



IAS – 2012 Main

Explain how flatness of a surface is measured with an optical flat.

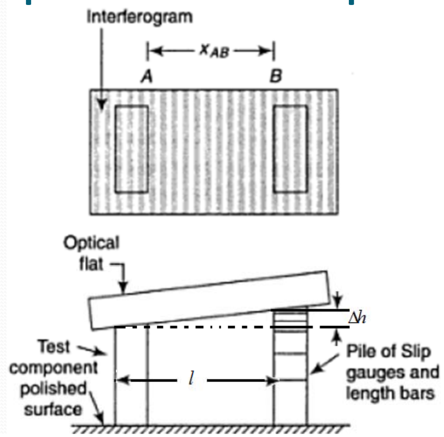
[12 marks]

IES – 2012 Conventional

Write in short about optical flat. Two fringe patterns are supplied for two completely different surfaces using optical flat, name the types of surfaces, and draw if required

Fig. Fringe patterns for two completely different types of surfaces.

Optical flat as a comparator



$$\Delta h = \frac{n\lambda l}{2}$$

Where l = separation of edges

n = number of fringes / cm

Δh = The difference of height between gauges

λ = wevlength of monochromatic light

A cadmium lamp employs an optical filter to generate monochromatic light of wavelength $\lambda = 0.509\ \mu m$. A set of available slip gauges wrung together have been used as a comparator of height of a test component which has been placed a distance of 10 cm from the pile of slip gauges. An optically flat glass plate was placed as shown in Fig. 8.10 and it formed a tilted surface. The number of fringes observed in the 10-cm separation distance were found to be 12.

(a) Determine the height difference between slip gauges and test sample, and

(b) The angle of tilt of the optically flat glass plate at this test position.

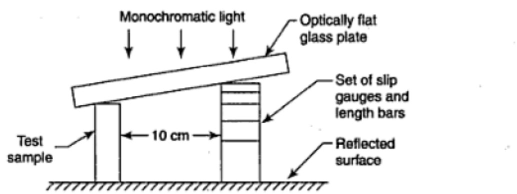
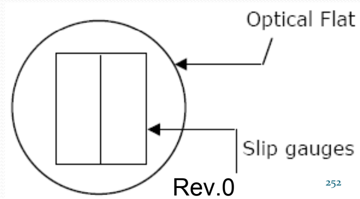


Fig. 8.10 *Test set up of a comparator for height measurements*

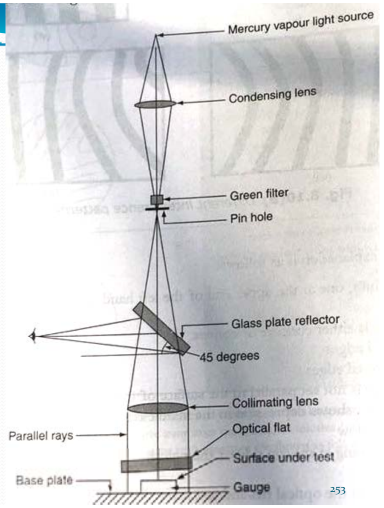
GATE - 2003

Two slip gauges of 10 mm width measuring 1.000 mm and 1.002 mm are kept side by side in contact with each other lengthwise. An optical flat is kept resting on the slip gauges as shown in the figure. Monochromatic light of wavelength 0.0058928 mm is used in the inspection. The total number of straight fringes that can be observed on both slip gauges is

(a) 2 (b) 6
(c) 8 (d) 13



NPL Flatness Interferometer



253

Parallelism Error

- In case of large-length slip gauges, the parallelism of surfaces can also be measured by placing the gauge on a rotary table in a specific position and reading number 1 can be taken.
- The number of fringes obtained is the result of the angle that the gauge surface makes with the optical flat. (n_1)
- Then the table is turned through 180° and reading number 2 can be taken. (n_2)
- The change in distance between the gauge and optical flat = λ/2

$$Parallelism\ Error = \frac{(n_2 - n_1)}{4} \times \lambda$$

254

GATE – 2011 (PI)

Observation of a slip gauge on a flatness interferometer produced fringe counts numbering 10 and 14 for two readings. The second reading is taken by rotating the set-up by 180°. Assume that both faces of the slip gauge are flat and the wavelength of the radiation is 0.5086 μm. The parallelism error (in μm) between the two faces of the slip gauge is

(a) 0.2543 (b) 1.172

(c) 0.5086 (d) 0.1272

255

Talysurf

- It is based upon measuring the generated noise due to dry friction of a metallic blade which travels over the surface under consideration.
- If the frictional force is made small enough to excite the blade, and not the entire system, then the noise will be proportional to surface roughness, and independent of the measured specimen size and material.
- The specimen surface roughness was measured by a widely used commercial instrument (Talysurf 10), and the prototype transducer.

256

Clinometer

- An optical device for measuring elevation angles above horizontal.
- Compass clinometers are fundamentally just magnetic compasses held with their plane vertical so that a plummet or its equivalent can point to the elevation of the sight line.
- The clinometer can read easily and accurately angles of elevation that would be very difficult to measure in any other simple and inexpensive way.
- A fairly common use of a clinometer is to measure the height of trees.

258

Clinometer

259

Autocollimator

- An optical instrument for non-contact measurement of small angles or small angular tilts of a reflecting surface.
- Used to align components and measure deflections in optical or mechanical systems.
- An autocollimator works by projecting an image onto a target mirror, and measuring the deflection of the returned image against a scale, either visually or by means of an electronic detector.
- A visual autocollimator can measure angles as small as 0.5 arcsecond, while an electronic autocollimator can be up to 100 times more accurate.

260

- Visual autocollimators are used for lining up laser rod ends and checking the face parallelism of optical windows and wedges.
- Electronic and digital autocollimators are used as angle measurement standards, for monitoring angular movement over long periods of time and for checking angular position repeatability in mechanical systems.
- Servo autocollimators are specialized compact forms of electronic autocollimators that are used in high speed servo feedback loops for stable platform applications.

261

Autocollimator

262

GATE - 1998

Auto collimator is used to check

(a) Roughness

(b) Flatness

(c) Angle

(d) Automobile balance.

263

GATE – 2009 (PI)

An autocollimator is used to

(a) measure small angular displacements on flat surface

(b) compare known and unknown dimensions

(c) measure the flatness error

(d) measure roundness error between centers

264

GATE – 2014

The flatness of a machine bed can be measured using

(*a*) Vernier calipers

(*b*) Auto collimator

(*c*) Height gauge

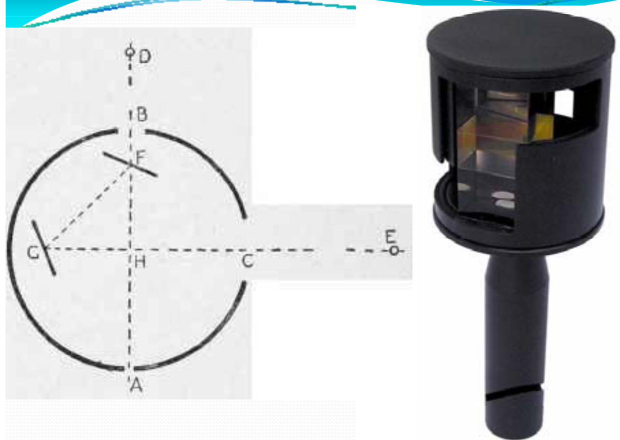
(*d*) Tool maker's microscope

265

Optical Square

- An Optical square consists of a small cylindrical metal box, about 5 cm in diameter and 12.5 cm deep, in which two mirrors are placed at an angle of 45° to each other and at right angles to the plane of the instrument.
- One mirror(horizon glass) is half silvered and other(index glass) is wholly silvered.
- The optical square belongs to a reflecting instruments which measure angles by reflection. Angle between the first incident ray and the last reflected ray is 90°
- Used to find out the foot of the perpendicular from a given point to a line.
- Used to set out right angles at a given point on a line in the field.
- Two mirrors may be replaced by two prisms.

266



An Optical Square

267

ISRO-2010

Optical square is

(a) Engineer's square having stock and blade set at 90°

(b) A constant deviation prism having the angle of deviation between the incident ray and reflected ray, equal to 90°

(c) A constant deviation prism having the angle of deviation between the incident ray and reflected ray, equal to 45°

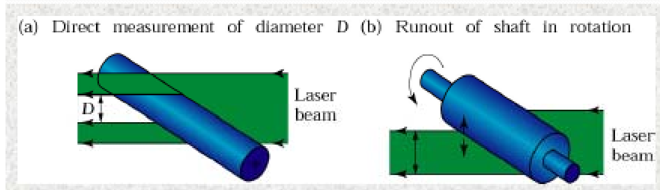
(d) Used to produce interference fringes

268

Laser Scanning Micrometer

- The LSM features a high scanning rate which allows inspection of small workpiece even if they are fragile, at a high temperature, in motion or vibrating.
- Applications :
  - Measurement of outer dia. And roundness of cylinder,
  - Measurement of thickness of film and sheets,
  - Measurement of spacing if IC chips,
  - Measurement of forms,
  - Measurement of gap between rollers.

269



270

IES - 1998

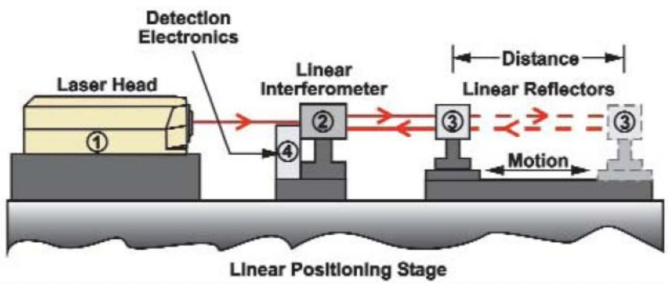
Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I (Measuring Device)		List-II (Parameter Measured)
A. Diffraction grating	1.	Small angular deviations on long flat surfaces
B. Optical flat	2.	On-line measurement of moving parts
C. Auto collimators	3.	Measurement of gear pitch
D. Laser scan micrometer	4.	Surface texture using interferometer
	5.	Measurement of very small displacements

Code:	A	B	C	D		A	B	C	D
(a)	5	4	2	1	(b)	3	5	1	2
(c)	3	5	4	1	(d)	5	4	1	2

Laser interferometer

- Laser interferometers represent the ultimate feedback device for high-precision motion control application.
- The combination of high resolution and outstanding accuracy has made it the ideal transducer for wafer steppers, flat panel inspection, and high-accuracy laser micromachining.
- A laser interferometer system employs a highly stabilized light source and precision optics to accurately measure distances.
- An additional advantage is that interferometers measure distances directly at the workpiece.



GATE-2014

Which one of the following instruments is widely used to check and calibrate geometric features of machine tools during their assembly?

(*a*) Ultrasonic probe

(*b*) Coordinate Measuring Machine (CMM)

(*c*) Laser interferometer

(*d*) Vernier calipers

Ultrasonic Probe

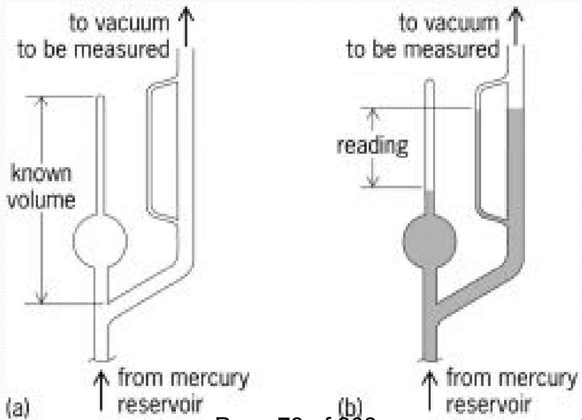
- Ultrasonic sensors are used in many fields.
- Key features of ultrasound transducers change depending on the propagation medium (solid, liquid, or air).
- Most important application is distance measurement.
- Common applications associated with distance measurement are
  - Presence detection
  - Identification of objects
  - The measurement of the shape and orientation of workpiece.
  - Collision avoidance
  - Room surveillance
  - Liquid level and flow measurement

Ultrasonic Probe

- Low accuracy, low reliability due to reflection of a transmitted signals.
- Limited range
- In the short fixed distance and controlled atmosphere (temperature and humidity) excellent performance can be achieved.
- Depending upon application different types of transdures are used. Most commonly used 40 KHz ceramic based transducers.

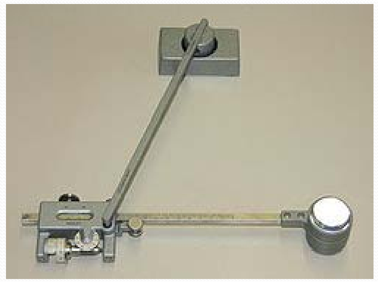
McLeod gauge

- Used to measure vacuum by application of the principle of Boyle's law.
- Works on the principle, "Compression of known volume of low pressure gas to higher pressure and measuring resulting volume & pressure, one can calculate initial pressure using Boyle's Law equation."
- Pressure of gases containing vapours cannot normally measured with a McLeod gauge, for the reason that compression will cause condensation .
- A pressure from 0.01 micron to 50 mm Hg can be measured. Generally McLeod gauge is used for calibration purpose.



Planimeter

- A device used for measuring the area of any plane surface by tracing the boundary of the area.

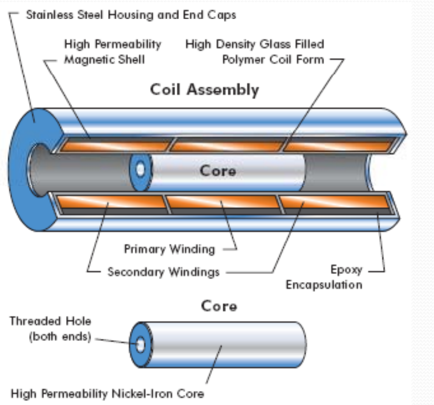


LVDT

- Acronym for Linear Variable Differential Transformer, a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal.
- LVDT linear position sensors are readily available that can measure movements as small as a few millionths of an inch up to several inches, but are also capable of measuring positions up to ±20 inches (±0.5 m).
- A **rotary variable differential transformer** (**RVDT**) is a type of electrical transformer used for measuring angular displacement.

280

LVDT



281

GATE - 1992

Match the instruments with the physical quantities they measure:

Instrument		**Measurement**
(A) Pilot-tube	(1)	R.P.M. of a shaft
(B) McLeod Gauge	(2)	Displacement
(C) Planimeter	(3)	Flow velocity
(D) LVDT	(4)	Vacuum
	(5)	Surface finish
	(6)	Area

Codes:	A	B	C	D		A	B	C	D
(a)	4	1	2	3	(b)	3	4	6	2
(c)	4	2	1	3	(d)	3	1	2	4

282

Tool Maker's Microscope

An essential part of engineering inspection, measurement and calibration in metrology labs. Hence is used to the following:

- Examination of form tools, plate and template gauges, punches and dies, annular grooved and threaded hobs etc.
- Measurement of glass graticules and other surface marked parts.
- Elements of external thread forms of screw plug gauges, taps, worms and similar components.
- Shallow bores and recesses.

283

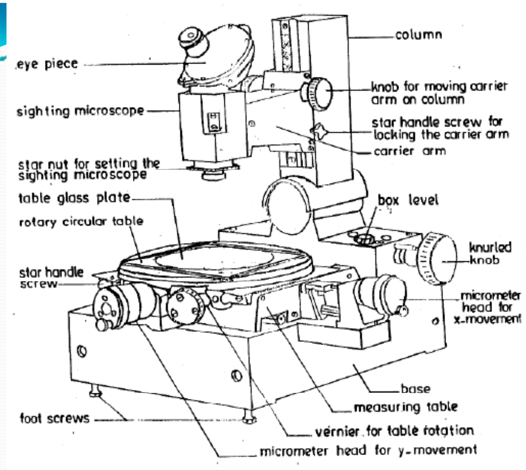


Fig.1 Tool Maker's Microscope

284

GATE - 2004

Match the following

Feature to be inspected	**Instrument**
P Pitch and Angle errors of screw thread	1. Auto Collimator
Q Flatness error of a surface plate	2. Optical Interferometer
R Alignment error of a machine slide way	3. Dividing Head and Dial Gauge
S Profile of a cam	4. Spirit Level
	5. Sine bar
	6. Tool maker's Microscope

(a) P-6 Q-2 R-4 S-6 (b) P-5 Q-2 R-1 S-6

(c) P-6 Q-4 R-1 S-3 (d) P-1 Q-4 R-4 S-2

285

Telescopic Gauges

- Used to measure a bore's size, by transferring the internal dimension to a remote measuring tool.
- They are a direct equivalent of inside callipers and require the operator to develop the correct feel to obtain repeatable results.

286

GATE - 1995

List I (Measuring instruments)		**List II** (Application)
(A) Talysurf	1.	T-slots
(B) Telescopic gauge	2.	Flatness
(C) Transfer callipers	3.	Internal diameter
(D) Autocollimator	4.	Roughness

Codes:	A	B	C	D		A	B	C	D
(a)	4	1	2	3	(b)	4	3	1	2
(c)	4	2	1	3	(d)	3	1	2	4

287

Coordinate Measuring Machine (CMM)

- An instrument that locates point coordinates on three dimensional structures mainly used for quality control applications.
- The highly sensitive machine measures parts down to the fraction of an inch.
- Specifically, a CMM contains many highly sensitive air bearings on which the measuring arm floats.

288

Advantages,

- can automate inspection process
- less prone to careless errors
- allows direct feedback into computer system

Disadvantages,

- Costly
- fixturing is critical
- requires a very good tolerance model

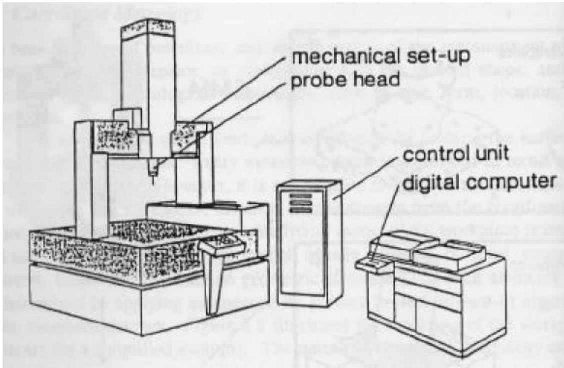
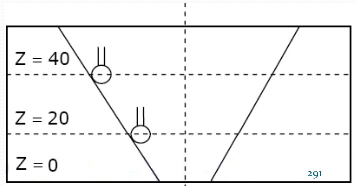


Figure 1: Components of a CMM

GATE - 2010

A taper hole is inspected using a CMM, with a probe of 2 mm diameter. At a height, Z = 10 mm from the bottom, 5 points are touched and a diameter of circle (not compensated for probe size) is obtained as 20 mm. Similarly, a 40 mm diameter is obtained at a height Z = 40 mm. the smaller diameter (in mm) of hole at Z = 0 is

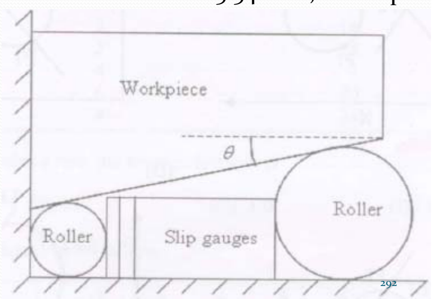
(a) 13.334
(b) 15.334
(c) 15.442
(d) 15.542



GATE -2008 (PI)

An experimental setup is planned to determine the taper of workpiece as shown in the figure. If the two precision rollers have radii 8 mm and 5 mm and the total thickness of slip gauges inserted between the rollers is 15.54 mm, the taper angle θ is

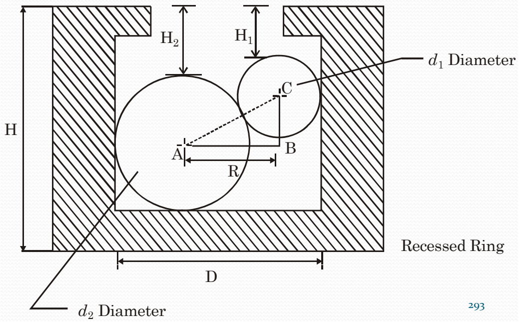
(a) 6 degree
(b) 10 degree
(c) 11 degree
(d) 12 degree



GATE -2014

The diameter of a recessed ring was measured by using two spherical balls of diameter d_2 = 60 mm and d_1 = 40 mm as shown in the figure.

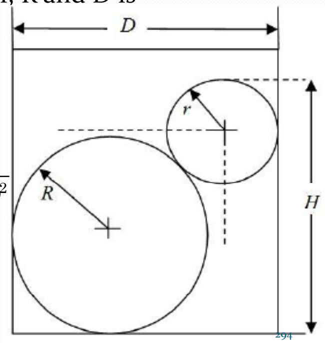
The distance H_2 = 35.55 mm and H_1 = 20.55 mm. The diameter (D, in mm) of the ring gauge is ....



GATE-2016

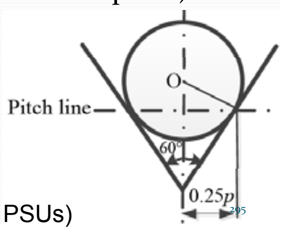
For the situation shown in the figure below the expression for H in terms of r, R and D is

(a) $H = D + \sqrt{r^2 + R^2}$
(b) $H = (R + r) + (D + r)$
(c) $H = (R + r) + \sqrt{D^2 - R^2}$
(d) $H = (R + r) + \sqrt{2D(R + r) - D^2}$



GATE-2018 (PI)

In a V-thread, a wire is fitted such that it makes contact with the flank of the thread on the pitch line as shown in the figure. If the pitch p of the thread is 3 mm and the included angle is 60°, the diameter (in mm, up to one decimal place) of the wire is ______



Metal Forming

By S K Mondal

1

Four Important forming techniques are:

- **Rolling:** The process of plastically deforming metal by passing it between rolls.
- **Forging:** The workpiece is compressed between two opposing dies so that the die shapes are imparted to the work.
- **Extrusion:** The work material is forced to flow through a die opening taking its shape
- **Drawing:** The diameter of a wire or bar is reduced by pulling it through a die opening (bar drawing) or a series of die openings (wire drawing)

2

Terminology

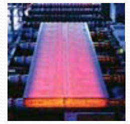
Semi-finished product

- **Ingot:** is the first solid form of steel.
- **Bloom:** is the product of first breakdown of ingot has square cross section 6 x 6 in. or larger
- **Billet:** is hot rolled from a bloom and is square, 1.5 in. on a side or larger.
- **Slab:** is the hot rolled ingot or bloom rectangular cross section 10 in. or more wide and 1.5 in. or more thick.


Ingot


Bloom


Billet

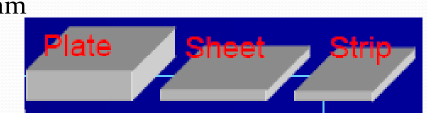

slab

3

Terminology

Mill product

- **Plate** is the product with thickness > 5 mm
- **Sheet** is the product with thickness < 5 mm and width > 600 mm
- **Strip** is the product with a thickness < 5 mm and width < 600 mm



4

Plastic Deformation

- Deformation beyond elastic limits.
- Due to slip, grain fragmentation, movement of atoms and lattice distortion.

5

Bulk Deformation Processes

- These processes involve large amount of plastic deformation.
- The cross-section of workpiece changes without volume change.
- The ratio cross-section area/volume is small.
- For most operations, hot or warm working conditions are preferred although some operations are carried out at room temperature.

6

Sheet-Forming Processes

- In sheet metal working operations, the cross-section of workpiece does not change—the material is only subjected to shape changes.
- The ratio cross-section area/volume is very high.
- Sheet metalworking operations are performed on thin (less than 5 mm) sheets, strips or coils of metal by means of a set of tools called punch and die on machine tools called stamping presses.
- They are always performed as cold working operations.

7

Strain Hardening

- When metal is formed in cold state, there is no recrystalization of grains and thus recovery from grain distortion or fragmentation does not take place.
- As grain deformation proceeds, greater resistance to this action results in increased hardness and strength i.e. strain hardening.

8

GATE-1995

A test specimen is stressed slightly beyond the yield point and then unloaded. Its yield strength

(a) Decreases

(b) Increases

(c) Remains same

(d) Become equal to UTS

9

IES-2013

Statement (I): At higher strain rate and lower temperature structural steel tends to become brittle.

Statement (II): At higher strain rate and lower temperature the yield strength of structural steel tends to increase.

(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

10

Recrystallisation Temperature (Rx temp.)

- "The minimum temperature at which the completed recrystallisation of a cold worked metal occurs within a specified period of approximately one hour".
- Rx temp. decreases strength and increases ductility.
- **If working above Rx temp., hot-working process whereas working below are cold-working process.**
- It involves replacement of cold-worked structure by a new set of strain-free, approximately equi-axed grains to replace all the deformed crystals. Contd.

11

Rx temp. depends on the amount of cold work a material has already received. The higher the cold work, the lower would be the Rx temp.

- Rx temp. varies between 1/3 to ½ melting paint.
- **For Pure metal Rx temp. = 0.3 x Melting temp. (Kelvin).**
- **For Alloy Rx temp. = 0.5 x Melting temp. (Kelvin).**
- Rx temp. of lead and Tin is below room temp.
- Rx temp. of Cadmium and Zinc is room temp.
- Rx temp. of Iron is 450°C and for steels around **1000°C**
- Finer is the initial grain size; lower will be the Rx temp

12

IES-2018

Recrystallization temperature is one at which

(a) crystals first start forming from molten metal when cooled

(b) new spherical crystals first begin to form from the old deformed ones when that strained metal is heated

(c) the allotropic form changes

(d) crystals grow bigger in size

13

IES-2016

The recrystallization behaviour of a particular metal alloy is specified in terms of recrystallization temperature, which is typically 1/3rd of the absolute melting temperature of a metal or an alloy and depends on several factors including the amount of

1. cold working and purity of the metal and alloy

2. hot working and purity of the metal and alloy

Which of the above is/are correct?

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

14

Grain growth

- Grain growth follows complete crystallization if the materials left at elevated temperatures.
- Grain growth does not need to be preceded by recovery and recrystallization; it may occur in all polycrystalline materials.
- In contrary to recovery and recrystallization, driving force for this process is reduction in grain boundary energy.
- In practical applications, grain growth is not desirable.
- Incorporation of impurity atoms and insoluble second phase particles are effective in retarding grain growth.
- Grain growth is very strongly dependent on temperature.

15

Malleability

- Malleability is the property of a material whereby it can be shaped when cold by hammering or rolling.
- A malleable material is capable of undergoing plastic deformation without fracture.
- A malleable material should be plastic but it is not essential to be so strong.
- Lead, soft steel, wrought iron, copper and aluminium are some materials in order of diminishing malleability.

16

17

- Working below recrystalization temp.

18

Advantages of Cold Working

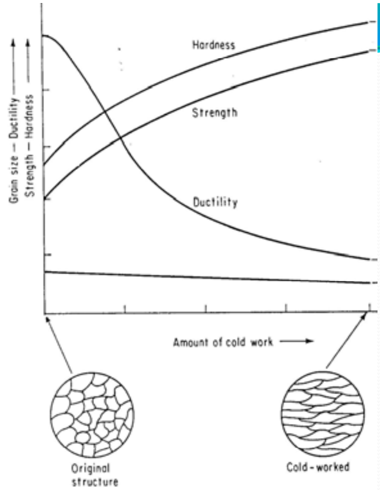
1. Better accuracy, closer tolerances
2. Better surface finish
3. Strain hardening increases strength and hardness
4. Grain flow during deformation can cause desirable directional properties in product
5. No heating of work required (less total energy)

19

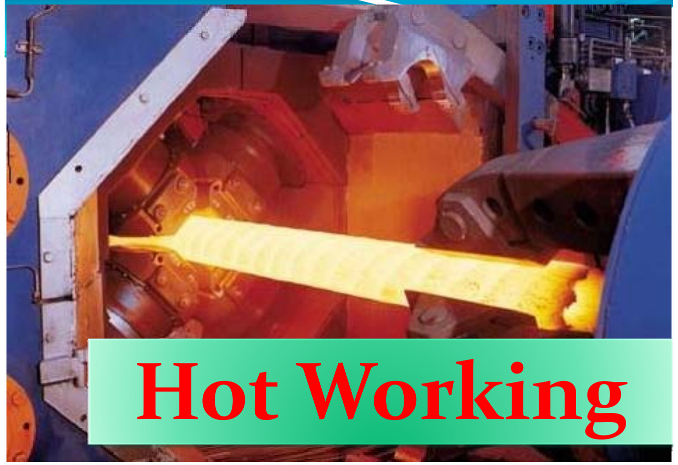
Disadvantages of Cold Working

1. Equipment of higher forces and power required
2. Surfaces of starting work piece must be free of scale and dirt
3. Ductility and strain hardening limit the amount of forming that can be done
4. In some operations, metal must be annealed to allow further deformation
5. Some metals are simply not ductile enough to be cold worked.

20



21



22

- Working above recrystalization temp.

23

Advantages of Hot Working

1. The porosity of the metal is largely eliminated.
2. The grain structure of the metal is refined.
3. The impurities like slag are squeezed into fibers and distributed throughout the metal.
4. The mechanical properties such as toughness, percentage elongation, percentage reduction in area, and resistance to shock and vibration are improved due to the refinement of grains.

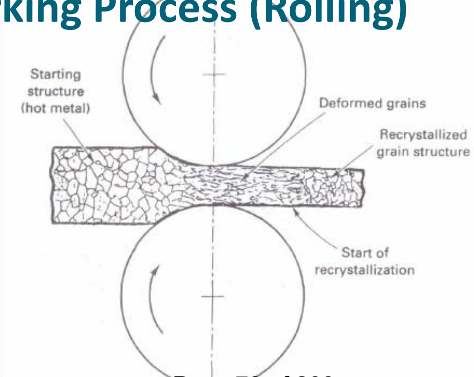
24

Dis-advantages of Hot Working

1. It requires expensive tools.
2. It produces poor surface finish, due to the rapid oxidation and scale formation on the metal surface.
3. Due to the poor surface finish, close tolerance cannot be maintained.

25

Micro-Structural Changes in a Hot Working Process (Rolling)



26

IES-2016

Statement (I) : Pursuant to plastic deformation of metals, the mechanical properties of the metals get changed.

Statement (II) : Mechanical properties of metals depend on grain size also which gets changed by plastic deformation.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

27

Annealing

•Annealing relieves the stresses from cold working – three stages: recovery, recrystallization and grain growth.
•During recovery, physical properties of the cold-worked material are restored without any observable change in microstructure.

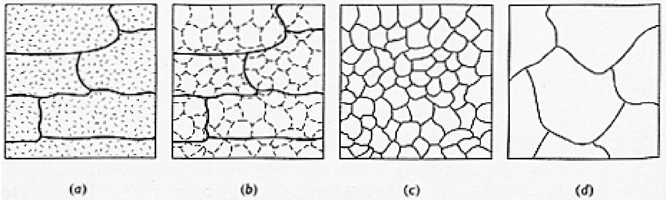


FIGURE 7-16 The effect of annealing temperature on the microstructure of cold-worked metals: (a) cold worked, (b) after recovery, (c) after recrystallization, and (d) after grain growth.

28

Warm Forming

- Deformation produced at temperatures intermediate to hot and cold forming is known as warm forming.
- Compared to cold forming, it reduces loads, increase material ductility.
- Compared to hot forming, it produce less scaling and decarburization, better dimensional precision and smoother surfaces.
- Warm forming is a precision forging operation carried out at a temperature range between 550–950°C. It is useful for forging of details with intricate shapes, with desirable grain flow, good surface finish and tighter dimensional tolerances.

29

Isothermal Forming

- During hot forming, cooler surfaces surround a hotter interior, and the variations in strength can result in non-uniform deformation and cracking of the surface.
- For temp.-sensitive materials deformation is performed under isothermal conditions.
- The dies or tooling must be heated to the workpiece temperature, sacrificing die life for product quality.
- Close tolerances, low residual stresses and uniform metal flow.

30

IES 2011

Assertion (A): Lead, Zinc and Tin are always hot worked.

Reason (R) : If they are worked in cold state they cannot retain their mechanical properties.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

31

GATE-2003

Cold working of steel is defined as working

(a) At its recrystallisation temperature
(b) Above its recrystallisation temperature
(c) Below its recrystallisation temperature
(d) At two thirds of the melting temperature of the metal

32

GATE-2002, ISRO-2012

Hot rolling of mild steel is carried out

(a) At recrystallisation temperature
(b) Between 100°C to 150°C
(c) Below recrystallisation temperature
(d) Above recrystallisation temperature

33

ISRO-2010

Materials after cold working are subjected to following process to relieve stresses

(a) Hot working
(b) Tempering
(c) Normalizing
(d) Annealing

34

IES – 2006

Which one of the following is the process to refine the grains of metal after it has been distorted by hammering or cold working?

(a) Annealing (b) Softening
(c) Re-crystallizing (d) Normalizing

35

IES – 2004

Consider the following statements:

In comparison to hot working, in cold working,

1. Higher forces are required
2. No heating is required
3. Less ductility is required
4. Better surface finish is obtained

Which of the statements given above are correct?

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 1 and 3 (d) 2, 3 and 4

36

IES – 2009

Consider the following characteristics:

1. Porosity in the metal is largely eliminated.
2. Strength is decreased.
3. Close tolerances cannot be maintained.

Which of the above characteristics of hot working is/are correct?

(a) 1 only (b) 3 only
(c) 2 and 3 (d) 1 and 3

37

IES – 2008

Consider the following statements:

1. Metal forming decreases harmful effects of impurities and improves mechanical strength.
2. Metal working process is a plastic deformation process.
3. Very intricate shapes can be produced by forging process as compared to casting process.

Which of the statements given above are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

38

IES – 2008

Cold forging results in improved quality due to which of the following?

1. Better mechanical properties of the process.
2. Unbroken grain flow.
3. Smoother finishes.
4. High pressure.

Select the correct answer using the code given below:

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1, 3 and 4

39

IES – 2004

Assertion (A): Cold working of metals results in increase of strength and hardness

Reason (R): Cold working reduces the total number of dislocations per unit volume of the material

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

40

IES – 2003

Cold working produces the following effects:

1. Stresses are set up in the metal
2. Grain structure gets distorted
3. Strength and hardness of the metal are decreased
4. Surface finish is reduced

Which of these statements are correct?

(a) 1and 2 (b) 1, 2 and 3
(c) 3 and 4 (d) 1 and 4

41

IES – 2000

Assertion (A): To obtain large deformations by cold working intermediate annealing is not required.

Reason (R): Cold working is performed below the recrystallisation temperature of the work material.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

42

ISRO-2009

In the metal forming process, the stresses encountered are

(a) Greater than yield strength but less than ultimate strength
(b) Less than yield strength of the material
(c) Greater than the ultimate strength of the material
(d) Less than the elastic limit

43

IES – 1997

In metals subjected to cold working, strain hardening effect is due to

(a) Slip mechanism
(b) Twining mechanism
(c) Dislocation mechanism
(d) Fracture mechanism

44

IES – 1996

Consider the following statements:

When a metal or alloy is cold worked

1. It is worked below room temperature.
2. It is worked below recrystallisation temperature.
3. Its hardness and strength increase.
4. Its hardness increases but strength does not increase.

Of these correct statements are

(a) 1 and 4 (b) 1 and 3
(c) 2 and 3 (d) 2 and 4

45

IES – 2006

Assertion (A): In case of hot working of metals, the temperature at which the process is finally stopped should not be above the recrystallisation temperature.

Reason (R): If the process is stopped above the recrystallisation temperature, grain growth will take place again and spoil the attained structure.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

46

IES – 1992

Specify the sequence correctly

(a) Grain growth, recrystallisation, stress relief

(b) Stress relief, grain growth, recrystallisation

(c) Stress relief, recrystallisation, grain growth

(d) Grain growth, stress relief, recrystallisation

47

IAS – 1996

For mild steel, the hot forging temperature range is

(a) 400°C to 600°C

(b) 700°C to 900°C

(c) 1000°C to 1200°C

(d) 1300°Cto 1500°C

48

IAS – 2004

Assertion (A): Hot working does not produce strain hardening.

Reason (R): Hot working is done above the re-crystallization temperature.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

49

IAS-2002

Assertion (A): There is good grain refinement in hot working.

Reason (R): In hot working physical properties are generally improved.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

50

IES-2008

Which one of the following is correct?

Malleability is the property by which a metal or alloy can be plastically deformed by applying

(a) Tensile stress (b) Bending stress

(c) Shear stress (d) Compressive stress

51

GATE-2017

It is desired to make a product having T-shaped cross-section from a rectangular aluminium block. Which one of the following processes is expected to provide the highest strength of the product?

(a) Welding (b) Casting

(c) Metal forming (d) Machining

52

53

Rolling

- **Definition:** The process of plastically deforming metal by passing it between rolls.
- Most widely used, high production and close tolerance.
- Friction between the rolls and the metal surface produces high compressive stress.
- Hot-working (unless mentioned cold rolling.)
- Metal will undergo bi-axial compression.

54

GATE-2013

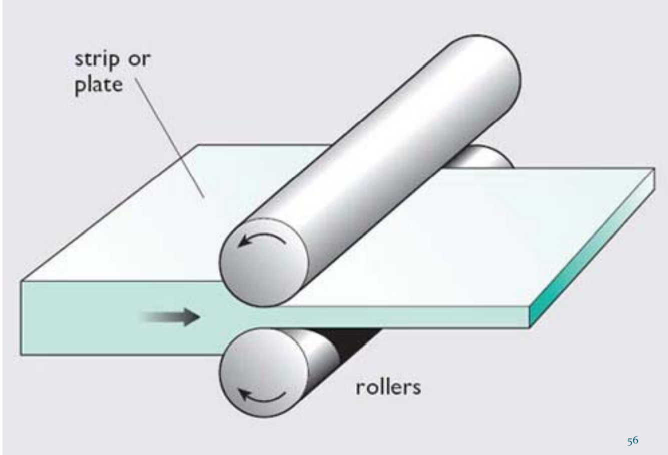
In a rolling process, the state of stress of the material undergoing deformation is

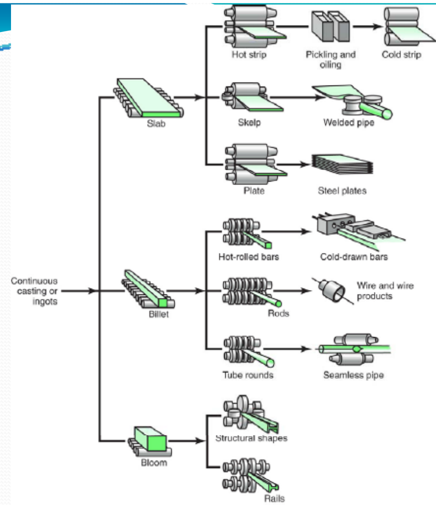
(a) pure compression

(b) pure shear

(c) compression and shear

(d) tension and shear

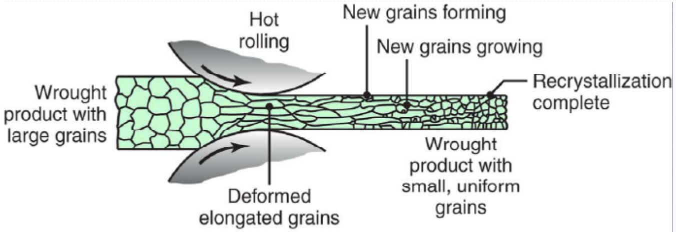




Hot Rolling

- Done above the recrystallization temp.
- Results fine grained structure.
- Surface quality and final dimensions are less accurate.
- Breakdown of ingots into blooms and billets is done by hot-rolling. This is followed by further hot-rolling into plate, sheet, rod, bar, pipe, rail.
- Hot rolling is terminated when the temp. falls to about (50 to 100°C) above the recrystallization temp.

Change in grains structure in Hot-rolling



Hot rolling is an effective way to reduce grain size in metals for improved strength and ductility.

IAS – 2001

Consider the following characteristics of rolling process:

1. Shows work hardening effect
2. Surface finish is not good
3. Heavy reduction in areas can be obtained

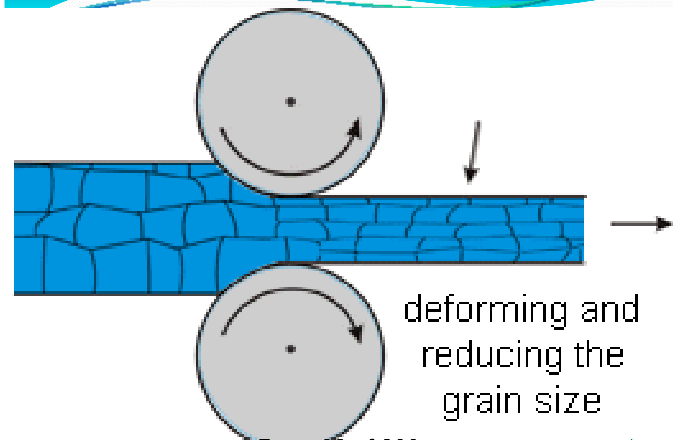
Which of these characteristics are associated with hot rolling?

(a) 1 and 2 (b) 1 and 3

(c) 2 and 3 (d) 1, 2 and 3

Cold Rolling

- Done below the recrystallization temp..
- Products are sheet, strip, foil etc. with good surface finish and increased mechanical strength with close product dimensions.
- Performed on four-high or cluster-type rolling mills. (Due to high force and power)



ISRO-2006

Which of the following processes would produce strongest components?

(a) Hot rolling

(b) Extrusion

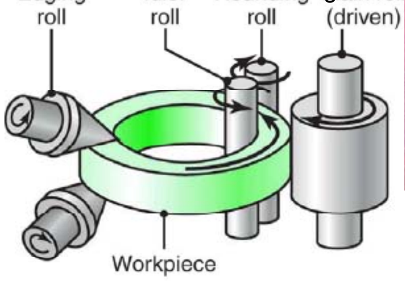
(c) Cold rolling

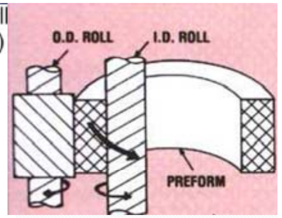
(d) Forging

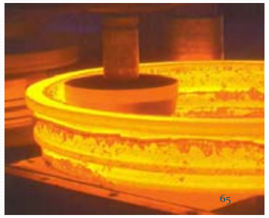
Ring Rolling

- Ring rolls are used for tube rolling, ring rolling.
- As the rolls squeeze and rotate, the wall thickness is reduced and the diameter of the ring increases.
- Shaped rolls can be used to produce a wide variety of cross-section profiles.
- Ring rolls are made of spheroidized graphite bainitic and pearlitic matrix or alloy cast steel base.

64







65

ISRO-2009

Ring rolling is used

(a) To decrease the thickness and increase diameter

(b) To increase the thickness of a ring

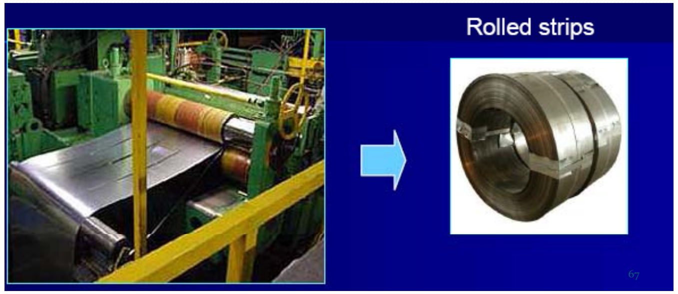
(c) For producing a seamless tube

(d) For producing large cylinder

66

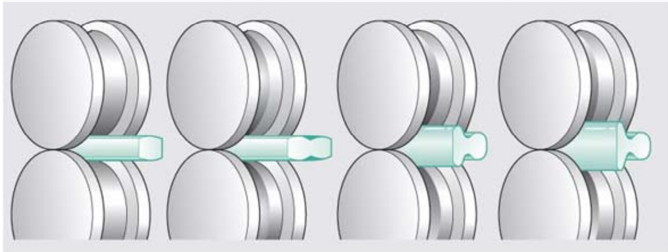
Sheet rolling

- In sheet rolling we are only attempting to reduce the cross section thickness of a material.



67

Roll Forming

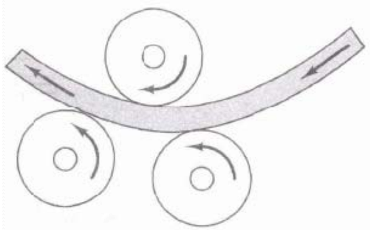


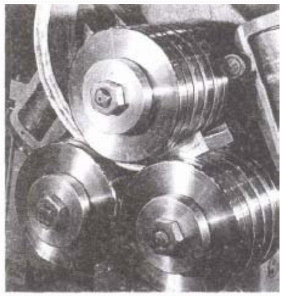
68

Roll Bending

- A continuous form of three-point bending is roll bending, where plates, sheets, and rolled shapes can be bent to a desired curvature on forming rolls.
- Upper roll being adjustable to control the degree of curvature.

69





70

IES – 2006

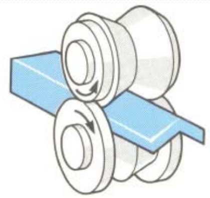
Which one of the following is a continuous bending process in which opposing rolls are used to produce long sections of formed shapes from coil or strip stock?

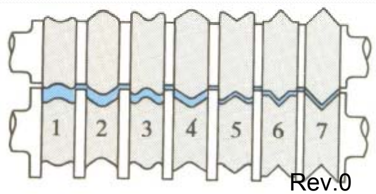
(a) Stretch forming (b) Roll forming

(c) Roll bending (d) Spinning

71

Shape rolling





72

Pack rolling

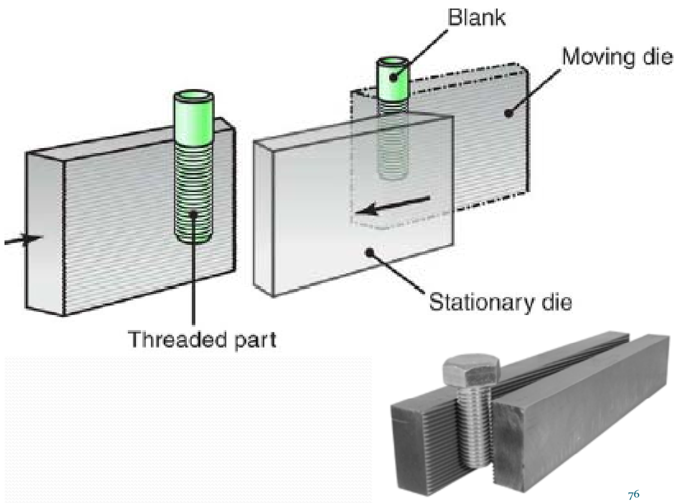
- Pack rolling involves hot rolling multiple sheets of material at once, such as aluminium foil.
- Improved productivity
- Aluminum sheets (aluminum foil)
  - Matte, satin side – foil-to-foil contact
  - Shiny, bright side – foil-to-roll contact due to high contact stresses with polished rolls
- A thin surface oxide film prevents their welding

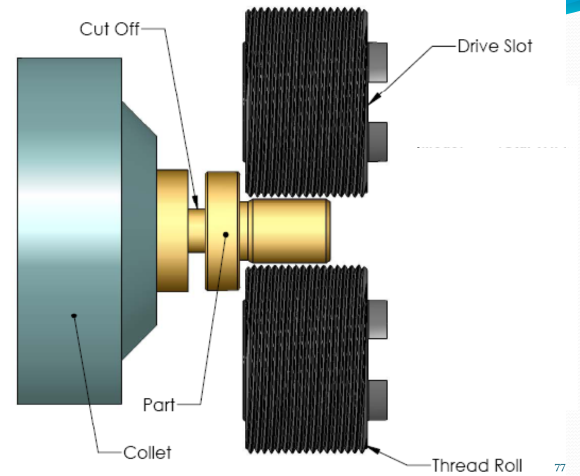
Thread rolling

- Used to produce threads in substantial quantities.
- This is a cold-forming process in which the threads are formed by rolling a thread blank between hardened dies that cause the metal to flow radially into the desired shape.
- No metal is removed, greater strength, smoother, harder, and more wear-resistant surface than cut threads.

Thread rolling contd....

- Major diameter is always greater than the diameter of the blank.
- Blank diameter is little larger (0.002 inch) than the pitch diameter of the thread.
- Restricted to ductile materials.





IES – 1992, GATE-1992(PI)

Thread rolling is restricted to

(a) Ferrous materials

(b) Ductile materials

(c) Hard materials

(d) None of the above

IES – 1993, GATE-1989(PI)

The blank diameter used in thread rolling will be

(a) Equal to minor diameter of the thread

(b) Equal to pitch diameter of the thread

(c) A little large than the minor diameter of the thread

(d) A little larger than the pitch diameter of the thread

IES – 2013 Conventional

Write two advantages of thread rolling and explain with figure two-die cylindrical machine.

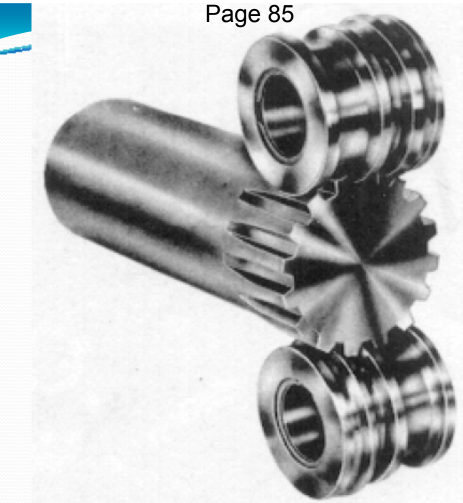
[5 Marks]

Manufacture of gears by rolling

- The straight and helical teeth of disc or rod type external steel gears of small to medium diameter and module are generated by cold rolling.
- High accuracy and surface integrity.
- Employed for high productivity and high quality. (costly machine)
- Larger size gears are formed by hot rolling and then finished by machining.

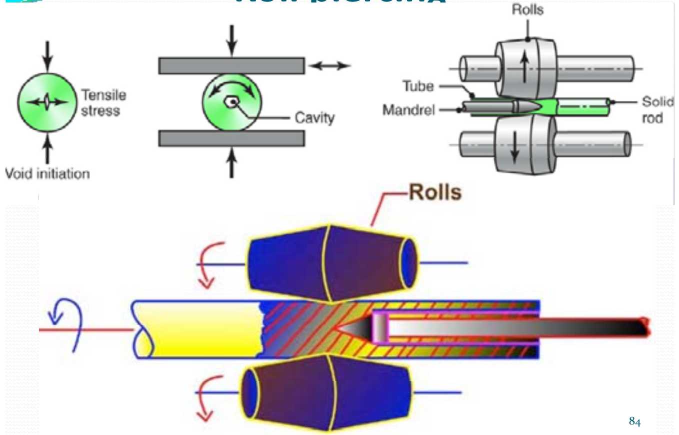
Fig. Gear rolling between three gear roll tools

82



83

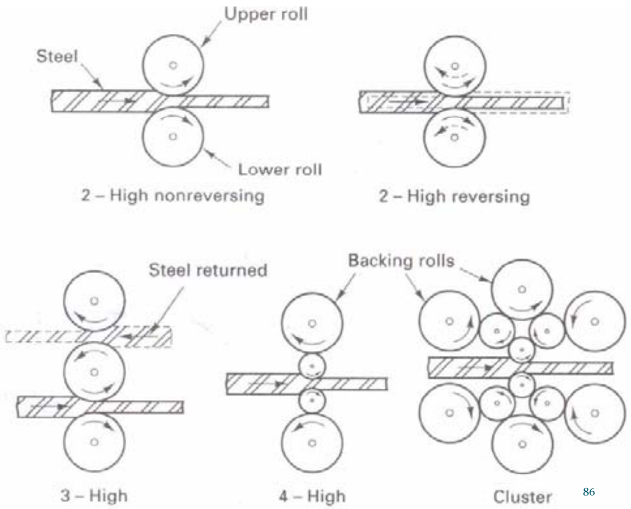
Roll piercing



84

- It is a variation of rolling called roll piercing.
- The billet or round stock is rolled between two rolls, both of them rotating in the same direction with their axes at an angle of 4.5 to 6.5 degree.
- These rolls have a central cylindrical portion with the sides tapering slightly. There are two small side rolls, which help in guiding the metal.
- Because of the angle at which the roll meets the metal, it gets in addition to a rotary motion, an additional axial advance, which brings the metal into the rolls.
- This cross-rolling action makes the metal friable at the centre which is then easily pierced and given a cylindrical shape by the central-piercing mandrel.

85



86

IAS – 2007

Match List I with List II and select the correct answer using the code given below the Lists:

List I (Type of Rolling Mill)	List II (Characteristic)
A. Two high non-reversing mills	1. Middle roll rotates by friction
B. Three high mills	2. By small working roll, power for rolling is reduced
C. Four high mills	3. Rolls of equal size are rotated only in one direction
D. Cluster mills	4. Diameter of working roll is very small

Code:	A	B	C	D		A	B	C	D
(a)	3	4	2	1	(b)	2	1	3	4
(c)	2	4	3	1	(d)	3	1	2	4

87

IAS – 2003

In one setting of rolls in a 3-high rolling mill, one gets

(a) One reduction in thickness

(b) Two reductions in thickness

(c) Three reductions in thickness

(d) Two or three reductions in thickness depending upon the setting

88

IAS – 2000

Rolling very thin strips of mild steel requires

(a) Large diameter rolls

(b) Small diameter rolls

(c) High speed rolling

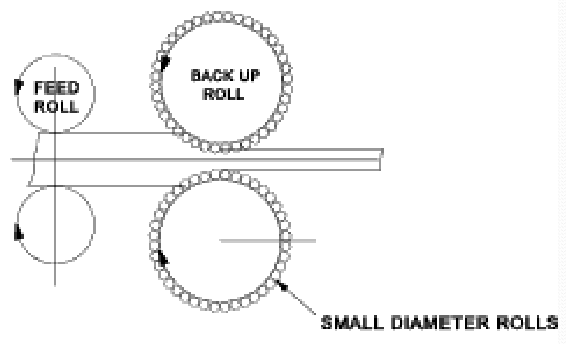
(d) Rolling without a lubricant

89

Planetary mill

- Consist of a pair of heavy backing rolls surrounded by a large number of planetary rolls.
- Each planetary roll gives an almost constant reduction to the slab as it sweeps out a circular path between the backing rolls and the slab.
- As each pair of planetary rolls ceases to have contact with the work piece, another pair of rolls makes contact and repeat that reduction.
- The overall reduction is the summation of a series of small reductions by each pair of rolls. Therefore, the planetary mill can reduce a slab directly to strip in one pass through the mill.
- The operation requires feed rolls to introduce the slab into the mill, and a pair of planishing rolls on the exit to improve the surface finish.

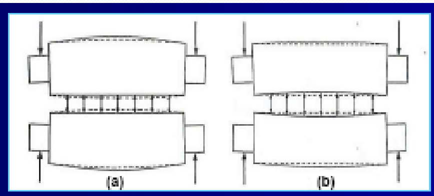
90



PLANETARY ROLLING MILL

91

Camber



(a) The use of cambered rolls to compensate for roll bending.

(b) Uncambered rolls give variation of thickness.

- Camber can be used to correct the roll deflection (at only one value of the roll force).

92

IES – 1993

In order to get uniform thickness of the plate by rolling process, one provides

(a) Camber on the rolls

(b) Offset on the rolls

(c) Hardening of the rolls

(d) Antifriction bearings

93

Lubrication for Rolling

- Hot rolling of ferrous metals is done without a lubricant.
- Hot rolling of non-ferrous metals a wide variety of compounded oils, emulsions and fatty acids are used.
- Cold rolling lubricants are water-soluble oils, low-viscosity lubricants, such as mineral oils, emulsions, paraffin and fatty acids.

94

IAS – 2004

Assertion (A): Rolling requires high friction which increases forces and power consumption.

Reason (R): To prevent damage to the surface of the rolled products, lubricants should be used.

(a) Both A and R are individually true and R is the correct explanation of A

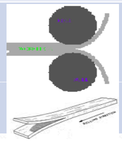
(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

95

Defects in Rolling

Defects		What is	Cause
Surface Defects		Scale, rust, scratches, pits, cracks	Inclusions and impurities in the materials
Wavy edges		Strip is thinner along its edges than at its centre.	Due to roll bending edges elongates more and buckle.
Alligatoring		Edge breaks	Non-uniform deformation

96

Defects in Rolling

Anisotropy

- Material develops anisotropy during cold rolling of sheet metal

Three principal true strain

$$In\ length\ direction,\ \varepsilon_l = \ln\left(\frac{L_f}{L_o}\right)$$

$$In\ width\ direction,\ \varepsilon_w = \ln\left(\frac{W_f}{W_o}\right)$$

$$In\ the\ thickness\ direction,\ \varepsilon_t = \ln\left(\frac{t_f}{t_o}\right)$$

$$For\ isotropic\ materials, \varepsilon_w = \varepsilon_t\ but\ in\ a\ cold\ rolled\ sheet\ \varepsilon_w \neq \varepsilon_t$$

$$Anisotropy\ ratio(r) = \varepsilon_w /$$

97

GATE – 2009 (PI)

Anisotropy in rolled components is caused by

(a) changes in dimensions

(b) scale formation

(c) closure of defects

(d) grain orientation

98

Example

A rectangular block 100 mm x 20 mm x 2 mm is elongated to 130 mm. If the anisotropy ratio = 2, find true strain in all directions.

99

IES-2003

Assertion (A): While rolling metal sheet in rolling mill, the edges are sometimes not straight and flat but are wavy.

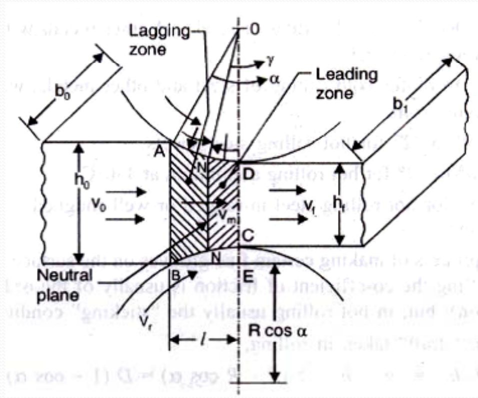
Reason (R) : Non uniform mechanical properties of the flat material rolled out result in waviness of the edges.

100

Formula in Rolling

101

Geometry of Rolling Process



102

Draft

- Total reduction or "draft" taken in rolling.

$$\Delta h = h_0 - h_f = 2(R - R\cos\alpha) = D(1-\cos\alpha)$$

- Usually, the reduction in blooming mills is about 100 mm and in slabbing mills, about 50 to 60 mm.

103

IAS-2012 Main

What is the significance of (1) angle of nip, and (2) angle of bite during rolling operation? How are they related to roll friction?

[10 marks]

104

GATE-2007

The thickness of a metallic sheet is reduced from an initial value of 16 mm to a final value of 10 mm in one single pass rolling with a pair of cylindrical rollers each of diameter of 400 mm. The bite angle in degree will be

(a) 5.936 (b) 7.936

(c) 8.936 (d) 9.936

105

GATE – 2012 Same Q in GATE – 2012 (PI)

In a single pass rolling process using 410 mm diameter steel rollers, a strip of width 140 mm and thickness 8 mm undergoes 10% reduction of thickness. The angle of bite in radians is

(a) 0.006 (b) 0.031

(c) 0.062 (d) 0.600

106

GATE-2017 (PI)

A metallic strip having a thickness of 12 mm is to be rolled using two steel rolls, each of 800 mm diameter. It is assumed that there is no change in width of the strip during rolling. In order to achieve 10% reduction in cross-sectional area of the strip after rolling, the angle subtended (in degrees) by the deformation zone at the center of the roll is

(a) 1.84 (b) 3.14 (c) 6.84 (d) 8.23

107

GATE-1998

A strip with a cross-section 150 mm x 4.5 mm is being rolled with 20% reduction of area using 450 mm diameter rolls. The angle subtended by the deformation zone at the roll centre is (in radian)

(a) 0.01 (b) 0.02

(c) 0.03 (d) 0.06

108

GATE-2018 (PI)

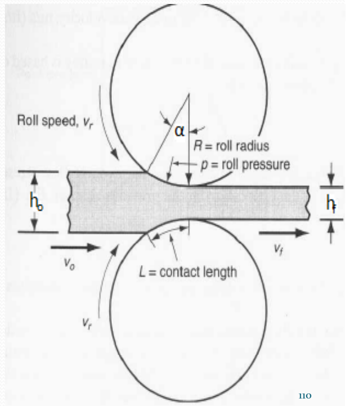
A 10 mm thick plate is rolled to 7 mm thickness in a rolling mill using 1000 mm diameter rigid rolls. The neutral point is located at an angle of 0.3 times the bite angle from the exit. The thickness (in mm, up to two decimal places) of the plate at the neutral point is ______

Roll strip contact length

- **Roll strip contact length**

$$L = R\alpha$$

[α must be in radian]



GATE-2004

In a rolling process, sheet of 25 mm thickness is rolled to 20 mm thickness. Roll is of diameter 600 mm and it rotates at 100 rpm. The roll strip contact length will be

(a) 5 mm (b) 39 mm

(c) 78 mm (d) 120 mm

For Unaided entry

$$\mu \geq \tan\alpha$$

Maximum Draft Possible

$$(\Delta h)_{max} = \mu^2 R$$

GATE 2011

The maximum possible draft in cold rolling of sheet increases with the

(a) increase in coefficient of friction

(b) decrease in coefficient of friction

(c) decrease in roll radius

(d) increase in roll velocity

GATE 2014

In a rolling process, the maximum possible draft, defined as the difference between the initial and the final thickness of the metal sheet, mainly depends on which pair of the following parameters?

P: Strain

Q: Strength of the work material

R: Roll diameter

S: Roll velocity

T: Coefficient of friction between roll and work

(*a*) Q, S (*b*) R, T

(*c*) S, T (*d*) P, R

GATE 2018

The maximum possible draft in rolling, which is the difference between initial and final thicknesses of the sheet metal, depends on

(a) rolling force

(b) roll radius

(c) roll width

(d) yield shear stress of the material

GATE-2016

A 300 mm thick slab is being cold rolled using roll of 600 mm diameter. If the coefficient of friction is 0.08, the maximum possible reduction (in mm) is __________

GATE-2015

In a rolling operation using rolls of diameter 500 mm , if a 25 mm thick plate cannot be reduced to less than 20 mm in one pass, the coefficient of friction between the roll and the plate is _______

GATE-2015

In a slab rolling operation , the maximum thickness reduction$(\Delta h)_{max}$ is given by $\Delta h_{max} = \mu^2 R$, where R is the radius of the roll and μ is the co-efficient of friction between the roll and the sheet. If μ = 0.1, the maximum angle subtended by the deformation zone at the centre of the roll (bite angle in degrees) is _____

IES – 1999

Assertion (A): In a two high rolling mill there is a limit to the possible reduction in thickness in one pass.

Reason (R): The reduction possible in the second pass is less than that in the first pass.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

Minimum Possible Thickness $(h_{f\,min})$

$$h_o - h_{f\,min} = \mu^2 R$$

GATE-2006

A 4 mm thick sheet is rolled with 300 mm diameter rolls to reduce thickness without any change in its width. The friction coefficient at the work-roll interface is 0.1. The minimum possible thickness of the sheet that can be produced in a single pass is

(a) 1.0 mm (b) 1.5 mm

(c) 2.5 mm (d) 3.7 mm

Number of pass needed

$$n = \frac{\Delta h_{required}}{\Delta h_{max}}$$

GATE – 2011 (PI)

The thickness of a plate is reduced from 30 mm to 10 mm by successive cold rolling passes using identical rolls of diameter 600 mm. Assume that there is no change in width. If the coefficient of friction between the rolls and the work piece is 0.1, the minimum number of passes required is

(a) 3 (b) 4 (c) 6 (d) 7

IES – 2001

A strip is to be rolled from a thickness of 30 mm to 15 mm using a two-high mill having rolls of diameter 300 mm. The coefficient of friction for unaided bite should nearly be

(a) 0.35 (b) 0.5

(c) 0.25 (d) 0.07

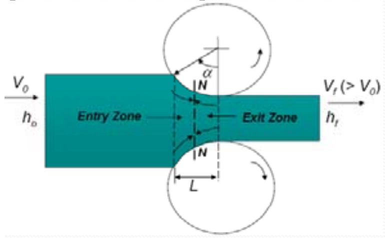
GATE-2014(PI)

A 80 mm thick steel plate with 400 mm width is rolled to 40 mm thickness in 4 passes with equal reduction in each pass, by using rolls of 800 mm diameter. Assuming the plane-strain deformation, what is the minimum coefficient of friction required for unaided rolling to be possible?

(a) 0.111 (b) 0.158 (c) 0.223 (d) 0.316

Neutral Point and Neutral Plane

The point where roll velocity equals work velocity is known as the *no-slip point or the neutral point.*



- V_o = input velocity
- V_f = final or output velocity
- R = roll radius
- h_o = back height
- h_f = output or final thickness
- α = angle of bite
- N-N = neutral point or no-slip point

$$\text{Backward slip} = \frac{V_r - V_o}{V_r} \times 100\%$$

$$\text{Forward slip} = \frac{V_f - V_r}{V_r} \times 100\%$$

To the left of the Neutral Point:

Velocity of the strip < Velocity of the roll

To the right of the Neutral Point:

Velocity of the strip > Velocity of the roll

127

GATE-1990 (PI)

While rolling a strip the peripheral velocity of the roll is ….A…..than the entry velocity of the strip and is ……B …..the exit velocity of the strip.

(a) less than/greater less

(b) Greater than/less than

128

IES - 2014

In the process of metal rolling operation, along the arc of contact in the roll gap there is a point called the neutral point, because

(a) On one side of this point, the work material is in tension and on the other side, the work material is in compression

(b) On one side of this point, the work material has velocity greater than that of the roll and on the other side, it has velocity lesser than that of the roll

(c) On one side of this point, the work material has rough surface finish and on the other side, the work material has very fine finish

(d) At this point there is no increase in material width, but on either side of neutral point, the material width increases

129

GATE -2008(PI)

In a rolling process, thickness of a strip is reduced from 4 mm to 3 mm using 300 mm diameter rolls rotating at 100 rpm. The velocity of the strip in (m/s) at the neutral point is

(a) 1.57 (b) 3.14 (c) 47.10 (d) 94.20

130

IES – 2002

In rolling a strip between two rolls, the position of the neutral point in the arc of contact does *not* depend on

(a) Amount of reduction (b) Diameter of the rolls

(c) Coefficient of friction (d) Material of the rolls

131

Selected Questions

The effect of friction on the rolling mill is

(a) always bad since it retards exit of reduced metal

(b) always good since it drags metal into the gap between the rolls

(c) advantageous before the neutral point

(d) disadvantageous after the neutral point

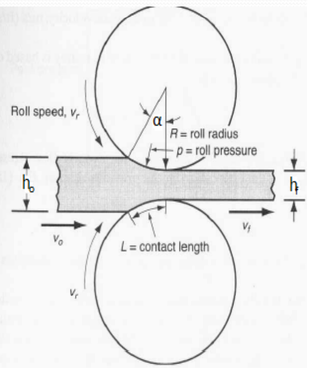
132

Continuity Equation

- Generally rolling increases the work width from an initial value of b_o to a final one of b_f and this is called *spreading.*
- The inlet and outlet volume rates of material flow must be the same, that is,

$$h_o b_o v_o = h_f b_f v_f$$

where v_o and v_f are the entering and exiting velocities of the work.



133

GATE-2014

A mild steel plate has to be rolled in one pass such that the final plate thickness is 2/3rd of the initial thickness, with the entrance speed of 10 m/min and roll diameter of 500 mm. If the plate widens by 2% during rolling, the exit velocity (in m/min) is ....

134

Elongation Factor or Elongation Co-efficient

$$E = \frac{L_1}{L_o} = \frac{A_o}{A_1} \quad \text{for single pass}$$

$$E^n = \frac{L_n}{L_o} = \frac{A_o}{A_n} \quad \text{for } n-\text{pass}$$

135

GATE-1992(PI)

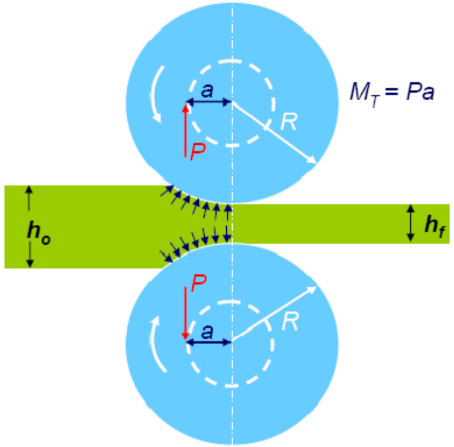
If the elongation factor during rolling of an ingot is 1.22. The minimum number of passes needed to produce a section 250 mm x 250 mm from an ingot of 750 mm x 750 mm are

(a) 8 (b) 9

(c) 10 (d) 12

136

Force, Torque and Power



Will be discussed in class

137

Projected length $\left(L_p\right) = R\sin\alpha = \sqrt{R\Delta h}\ \ , mm$

Projected Area $\left(A_p\right) = L_p \times b\ \ , mm^2$

Roll Separating Force $(F) = \sigma_o \times L_p \times b\ \ , N$

$[\sigma_o\ in\ N/mm^2\ i.e. MPa]$

Arm length $(a\ in\ mm) = 0.5L_p$ for hot rolling

$= 0.45L_p$ for cold rolling

Torque per roller $(T) = F \times \dfrac{a}{1000}$, Nm

Total power for two roller $(P) = 2T\omega\ , in\ W$

138

GATE-2016 (PI)

In a single-pass rolling operation, a 200 mm wide metallic strip is rolled from a thickness 10 mm to a thickness 6 mm. The roll radius is 100 mm and it rotates at 200 rpm. The roll-strip contact length is a function of roll radius and, initial and final thickness of the strip. If the average flow stress in plane strain of the strip material in the roll gap is 500 MPa, the roll separating force (in kN) is _______.

139

GATE-2008

In a single pass rolling operation, a 20 mm thick plate with plate width of 100 mm, is reduced to 18 mm. The roller radius is 250 mm and rotational speed is 10 rpm. The average flow stress for the plate material is 300 MPa. The power required for the rolling operation in kW is closest to

(a) 15.2 (b) 18.2

(c) 30.4 (d) 45.6

140

GATE-2017

A strip of 120 mm width and 8 mm thickness is rolled between two 300 mm - diameter rolls to get a strip of 120 mm width and 7.2 mm thickness. The speed of the strip at the exit is 30 m/min. There is no front or back tension. Assuming uniform roll pressure of 200 MPa in the roll bite and 100% mechanical efficiency, the minimum total power (in kW) required to drive the two rolls is___________

141

IAS -2017 Main

An annealed copper plate of 300 mm width and 20 mm thickness is rolled to 16 mm thickness in one pass. Considering radius of the roller as 400 mm, rotational speed of 80 rpm and average flow stress during rolling as 400 MPa, calculate the true strain and rolling force (kN).

[10 Marks]

142

IES – 2000, GATE-2010(PI)

In the rolling process, roll separating force can be decreased by

(a) Reducing the roll diameter

(b) Increasing the roll diameter

(c) Providing back-up rolls

(d) Increasing the friction between the rolls and the metal

143

IAS – 2007

Consider the following statements:

Roll forces in rolling can be reduced by

1. Reducing friction
2. Using large diameter rolls to increase the contact area.
3. Taking smaller reductions per pass to reduce the contact area.

Which of the statements given above are correct?

(a) 1 and 2 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

144

Assumptions in Rolling

1. Rolls are straight, rigid cylinders.
2. Strip is wide compared with its thickness, so that no widening of strip occurs (plane strain conditions).
3. The arc of contact is circular with a radius greater than the radius of the roll.
4. The material is rigid perfectly plastic (constant yield strength).
5. The co-efficient of friction is constant over the tool-work interface.

145

IES – 2001

Which of the following assumptions are correct for cold rolling?

1. The material is plastic.
2. The arc of contact is circular with a radius greater than the radius of the roll.
3. Coefficient of friction is constant over the arc of contact and acts in one direction throughout the arc of contact.

Select the correct answer using the codes given below:

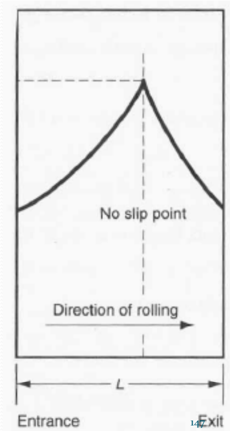
Codes:

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

146

IAS -2012 Main

What is "friction hill" ?



147

For IES Only

What is ragging?

- Ragging is the process of making certain fine grooves on the surface of the roll to increase the friction.
- In case of primary reduction rolling mills such as blooming or rough rolling mills for structural elements the rolls may ragged.

148

IFS – 2010

Calculate the neutral plane to roll 250 mm wide annealed copper strip from 2.5 mm to 2.0 mm thickness with 350 mm diameter steel rolls. Take $\mu = 0.05$ and $\sigma'_o = 180$ MPa.

[10-marks]

149

IAS – 1998

Match List - I (products) with List - II (processes) and select the correct answer using the codes given below the lists:

List – I	**List -II**
A. M.S. angles and channels	1. Welding
B. Carburetors	2. Forging
C. Roof trusses	3. Casting
D. Gear wheels	4. Rolling

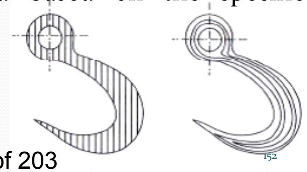
Codes:	A	B	C	D		A	B	C	D
(a)	1	2	3	4	(b)	4	3	2	1
(c)	1	2	4	3	(d)	4	3	1	2

150

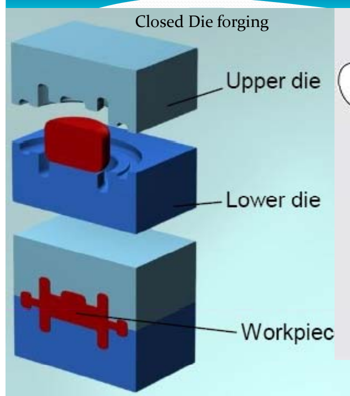
151

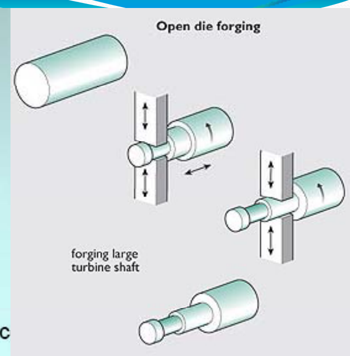
Forging

- Forging process is a metal working process by which metals or alloys are plastically deformed to the desired shapes by a compressive force applied with the help of a pair of dies.
- Because of the manipulative ability of the forging process, it is possible to closely control the grain flow in the specific direction, such that the best mechanical properties can be obtained based on the specific application.



152





153

IES-2016

Illustrate the difference between

(i) open die forging and

(ii) **closed die forging with appropriate sketches**

[4 Marks]

154

IES-2013

Statement (I): The dies used in the forging process are made in pair.

Statement (II): The material is pressed between two surfaces and the compression force applied, gives it a shape.

(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

155

Open and Closed die forging

- Depending upon complexity of the part forging is carried out as open die forging and closed die forging.
- In open die forging, the metal is compressed by repeated blows by a mechanical hammer and shape is manipulated manually.
- In closed die forging, the desired configuration is obtained by squeezing the workpiece between two shaped and closed dies.

156

Advantages of Forging

- Discrete shape of product can be produced.
- Mechanical properties and reliability of the materials increases due to improve in crystal structure.
- In forging favorable grain orientation of metal is obtained that strengthen the component but forging distorts the previously created uni-directional fibre.
- Forging reduces the grain size of the metal, which increases strength and toughness.
- Fatigue and creep strength increases.

157

Disadvantages of Forging

- Costly
- Poor dimensional accuracy and surface finish.
- Forging operations are limited to simple shapes and has limitations for parts having undercuts, re-entrant surfaces, etc

158

IES – 1996

Which one of the following is an advantage of forging?

(a) Good surface finish

(b) Low tooling cost

(c) Close tolerance

(d) Improved physical property.

159

IES-2013

In the forging process:

1. The metal structure is refined

2. Original unidirectional fibers are distorted.

3. Poor reliability, as flaws are always there due to intense working

4. Part are shaped by plastic deformation of material

(*a*) 1, 2 and 3 (*b*) 1, 3 and 4

(*c*) 1, 2 and 4 (*d*) 2, 3 and 4

160

IES – 2005

Consider the following statements:

1. **Forging reduces the grain size of the metal, which results in a decrease in strength and toughness.**
2. **Forged components can be provided with thin sections, without reducing the strength.**

Which of the statements given above is/are correct?

(a) Only 1 (b) Only 2

(c) Both 1 and 2 (d) Neither 1 nor 2

161

IES - 2012

Statement (I): It is difficult to maintain close tolerance in normal forging operation.

Statement (II): Forging is workable for simple shapes and has limitation for parts having undercuts.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

162

IES-2016

Consider the following statements about forging :

1. Forgings have high strength and ductility.

2. Forgings offer great resistance to impact and fatigue loads.

3. Forging assures uniformity in density as well as dimensions of the forged parts.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

163

ISRO-2013

Which of the following processes induce more stress in the metal?

(a) Hot rolling

(b) Forging

(c) Swaging

(d) Turning

164

Forgeability

- The forgeability of a metal can be defined as its capability to undergo deformation by forging without cracking.
- Metal which can be formed easily without cracking, with low force has good forgeability.
- Upsetting test and Hot-twist test are used to determine forgeability.
- Forgeability increases with temperature.

165

IES - 2012

Which of the following statements is correct for forging?

(a) Forgeability is property of forging tool, by which forging can be done easily.

(b) Forgeability decreases with temperature upto lower critical temperature.

(c) Certain mechanical properties of the material are influenced by forging.

(d) Pure metals have good malleability, therefore, poor forging properties.

166

Draft

- The draft provided on the sides for withdrawal of the forging.
- Adequate draft should be provided-at least 3^o for aluminum and 5 to 7^o for steel.
- Internal surfaces require more draft than external surfaces. During cooling, forging tends to shrink towards its centre and as a result, the external surfaces are likely to be separated, whereas the internal surfaces tend to cling to the die more strongly.

167

IES – 2006

Assertion (A): Forging dies are provided with taper or draft angles on vertical surfaces.

Reason (R): It facilitates complete filling of die cavity and favourable grain flow.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

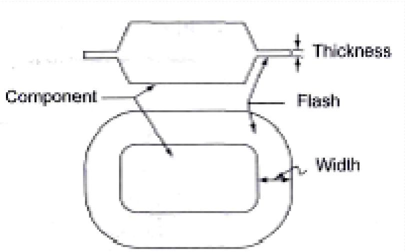
(c) A is true but R is false

(d) A is false but R is true

168

Flash

The excess metal added to the stock to ensure complete filling of the die cavity in the finishing impression is called Flash.



169

Flash Contd...

- A flash acts as a cushion for impact blows from the finishing impression and also helps to restrict the outward flow of metal, thus helping in filling of thin ribs and bosses in the upper die.
- The amount of flash depends on the forging size and may vary from 10 to 50 per cent.
- The forging load can be decreased by increasing the flash thickness.

170

IES - 2014

In hot die forging, thin layer of material all around the forging is

(a) Gutter space, which fills up hot gases

(b) Flash, the width of it is an indicator of the pressure developed in the cavity

(c) Coining, which indicates the quality of the forging

(d) Cavity, which is filled with hot impurities in the material

171

IES-2016

Statement (I) : In drop forging, the excess metal added to the stock for complete filling of the die cavity is called flash.

Statement (II) : Flash acts as a cushion against impact blows attributable to the finishing impression.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true

172

IAS – 2002

Consider the following statements related to forging:

1. Flash is excess material added to stock which flows around parting line.
2. Flash helps in filling of thin ribs and bosses in upper die.
3. Amount of flash depends upon forging force.

Which of the above statements are correct?

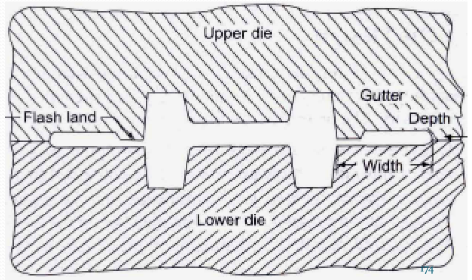
(a) 1, 2 and 3 (b) 1 and 2

(c) 1 and 3 (d) 2 and 3

173

Gutter

- In addition to the flash, provision should be made in the die for additional space so that any excess metal can flow and help in the complete closing of the die. This is called gutter.



174

Gutter Contd….

- Without a gutter, a flash may become excessively thick, not allowing the dies to close completely.
- Gutter depth and width should be sufficient to accommodate the extra, material.

175

IES – 1993, GATE-1994(PI)

Which one of the following manufacturing processes requires the provision of 'gutters'?

(a) Closed die forging

(b) Centrifugal casting

(c) Investment casting

(d) Impact extrusion

176

IES – 1997

Assertion (A): In drop forging besides the provision for flash, provision is also to be made in the forging die for additional space called gutter.

Reason (R): The gutter helps to restrict the outward flow of metal thereby helping to fill thin ribs and bases in the upper die.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

177

GATE-1989(PI)

At the last hammer stroke the excess material from the finishing cavity of a forging die is pushed into……………..

178

IES-2015

Which of the following statements apply to provision of flash gutter and flash land around the parts to be forged?

1. Small cavities are provided which are directly outside the die impression.
2. The volume of flash land and flash gutter should be about 20%-25% of the volume of forging.
3. Gutter is provided to ensure complete closing of the die.

(a) 1 and 2 only (b) 1 and 3 only

(c) 1, 2 and 3 (d) 2 and 3 only

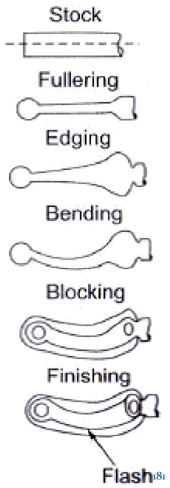
179

Sequential steps involved in closed die forging

Fullering or swaging	Reducing cross section and making it longer.
Edging or rolling	Preform shape. Gathers the material as required in the final forging.
Bending	Required for those parts which have a bent shape
Drawing or cogging	Like fullering but c/s of only one end is reduced
Flattening	Flatten the stock so that it fits properly into the finishing impression.
Blocking	Semi-finishing impression, Imparts to the forging it's general but not exact or final shape.
Finishing	Final impression, Flash land and Gutter provided to the die.
Trimming or cut off	Removal of flash present around forging

180

Example



181

IES – 1998

Which one of the following processes is most commonly used for the forging of bolt heads of hexagonal shape?

(a) Closed die drop forging

(b) Open die upset forging

(c) Close die press forging

(d) Open die progressive forging

182

IES – 2001

In the forging operation, fullering is done to

(a) Draw out the material

(b) Bend the material

(c) Upset the material

(d) Extruding the material

183

IES – 2003

A forging method for reducing the diameter of a bar and in the process making it longer is termed as

(a) Fullering (b) Punching

(c) Upsetting (d) Extruding

184

IES 2011

Which of the following processes belong to forging operation ?

1. Fullering

2. Swaging

3. Welding

(a) 1 and 2 only

(b) 2 and 3 only

(c) 1 and 3 only

(b) 1, 2 and 3 only

185

IES – 2005

The process of removing the burrs or flash from a forged component in drop forging is called:

(a) Swaging (b) Perforating

(c) Trimming (d) Fettling

186

IES – 2002

Consider the following steps involved in hammer forging a connecting rod from bar stock:

1. Blocking 2. Trimming

3. Finishing 4. Fullering 5. Edging

Which of the following is the correct sequence of operations?

(a) 1, 4, 3, 2 and 5

(b) 4, 5, 1, 3 and 2

(c) 5, 4, 3, 2 and 1

(d) 5, 1, 4, 2 and 3

187

IES – 2003

Consider the following steps in forging a connecting rod from the bar stock:

1. Blocking 2. Trimming

3. Finishing 4. Edging

Select the correct sequence of these operations using the codes given below:

Codes:

(a) 1-2-3-4 (b) 2-3-4-1

(c) 3-4-1-2 (d) 4-1-3-2

188

IAS – 2001

Match List I (Forging operations) with List II (Descriptions) and select the correct answer using the codes given below the Lists:

	List I	List II
A.	Flattening	1. Thickness is reduced continuously at different sections along length
B.	Drawing	2. Metal is displaced away from centre, reducing thickness in middle and increasing length
C.	Fullering	3. Rod is pulled through a die
D.	Wire drawing	4. Pressure a workpiece between two flat dies

Codes:

	A	B	C	D		A	B	C	D
(a)	3	2	1	4	(b)	4	1	2	3
(c)	3	1	2	4	(d)	4	2	1	3

189

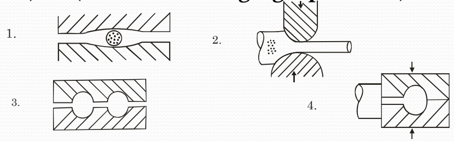
IES-2012 Conventional

In forging define the terms
(i) Edging
(ii) Fullering
and (iii) Flash

IAS – 2003

Match List I (Forging Operation) with List II (View of the Forging Operation) and select the correct answer using the codes given below the lists:

List-I (Forging Operation)	List-II (View of the Forging Operation)
(A) Edging	
(B) Fullering	
(C) Drawing	
(D) Swaging	

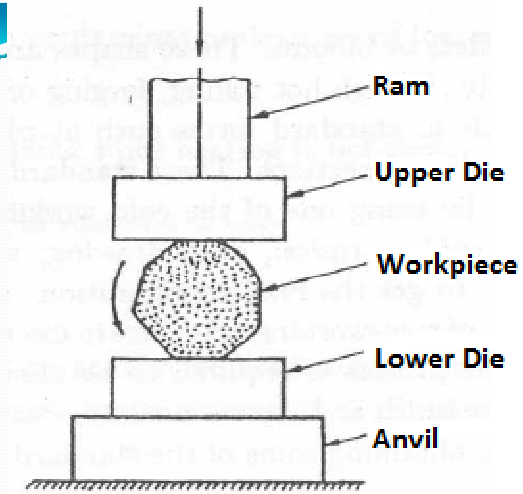


Codes:	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

Click to see file Page 4 – 5 -6

Drop Forging

- The drop forging die consists of two halves. The lower half of the die is fixed to the anvil of the machine, while the upper half is fixed to the ram. The heated stock is kept in the lower die while the ram delivers four to five blows on the metal, in quick succession so that the metal spreads and completely fills the die cavity. When the two die halves close, the complete cavity is formed.
- Drop forging is used to produce **small components.**



IES – 1994, ISRO-2010

In drop forging, forging is done by dropping

(a) The work piece at high velocity
(b) The hammer at high velocity.
(c) The die with hammer at high velocity
(d) a weight on hammer to produce the requisite impact.

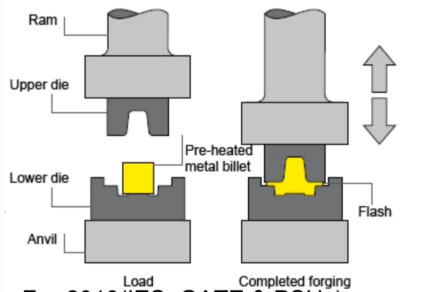
IAS – 2000

Drop forging is used to produce

(a) Small components
(b) Large components
(c) Identical Components in large numbers
(d) Medium-size components

Press Forging

- Metal is squeezed gradually by a hydraulic or mechanical press and component is produced in a single closing of die, hence the dimensional accuracy is much better than drop forging.



Advantages of Press Forging over Drop Forging

- Press forging is faster than drop forging
- Alignment of the two die halves can be more easily maintained than with hammering.
- Structural quality of the product is superior to drop forging.
- With ejectors in the top and bottom dies, it is possible to handle reduced die drafts.

IES 2011

Consider the following statements :

1. Any metal will require some time to undergo complete plastic deformation particularly if deforming metal has to fill cavities and corners of small radii.

2. For larger work piece of metals that can retain toughness at forging temperature it is preferable to use forge press rather than forge hammer.

(a) 1 and 2 are correct and 2 is the reason for 1
(b) 1 and 2 are correct and 1 is the reason for 2
(c) 1 and 2 are correct but unrelated
(d) 1 only correct

IFS-2011

What advantages does press forging have over drop forging ? Why are pure metals more easily cold worked than alloys ?

[5-marks]

Machine Forging

- Unlike the drop or press forging where the material is drawn out, in machine forging, the material is only upset to get the desired shape.

Upset Forging

- Increasing the diameter of a material by compressing its length.
- Employs split dies that contain multiple positions or cavities.

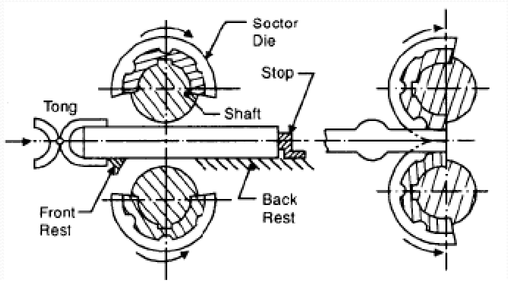
Roll Forging

- When the rolls are in the open position, the heated stock is advanced up to a stop. As the rolls rotate, they grip and roll down the stock. The stock is transferred to a second set of grooves. The rolls turn again and so on until the piece is finished.

Roll Forging

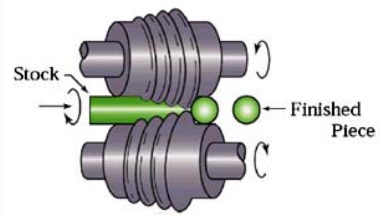
Contd....

- A rapid process.



Skew Rolling

- Skew rolling produces metal ball
- Round stock is fed continuously to two specially designed opposing rolls.
- Metal is forged by each of the grooves in the rolls and emerges from the end as a metal ball.



Smith Forging

- Blacksmith uses this forging method
- Quality of the product depends on the skill of the operator.
- Not used in industry.

IES – 2005

Match List I (Type of Forging) with List II (Operation) and select the correct answer using the code given below the Lists:

	List I		List II
A.	Drop Forging	1.	Metal is gripped in the dies and pressure is applied on the heated end
B.	Press Forging	2.	Squeezing action
C.	Upset Forging	3.	Metal is placed between rollers and pushed
D.	Roll Forging	4.	Repeated hammer blows

	A	B	C	D		A	B	C	D
(a)	4	1	2	3	(b)	3	2	1	4
(c)	4	2	1	3	(d)	3	1	2	4

IES – 2008

Match List-I with List-II and select the correct answer using the code given below the lists:

List-I (Forging Technique)	List-II (Process)
A. Smith Forging	1. Material is only upset to get the desired shape
B. Drop Forging	2.Carried out manually open dies
C. Press Forging	3. Done in closed impression dies by hammers in blows
D. Machine Forging	4. Done in closed impression dies by continuous squeezing force

Code:	A	B	C	D		A	B	C	D
(a)	2	3	4	1	(b)	4	3	2	1
(c)	2	1	4	3	(d)	4	1	2	3

For IES Only

High Velocity Forming (HVF)

- The process deforms metals by using very high velocities, provided on the movements of rams and dies.
- As K.E ∞ V^2, high energy is delivered to the metal with relatively small weights (ram and die).
- Cost and size of machine low.
- Ram strokes short (due to high acceleration)
- Productivity high, overall production cost low
- Used for Alloy steel, titanium, Al, Mg, to fabricate one piece complex components of smaller size like valve, rocket component.

208

IES-2013

Statement (I): In high velocity forming process, high energy can be transferred to metal with relatively small weight.

Statement (II): The kinetic energy is the function of mass and velocity.

(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

209

IFS-2011

Write four advantages of high velocity forming process.

[2-marks]

210

IAS-2011 Main

Compare Smith forging, drop forging, press forging and upset forging. Mention three points for each.

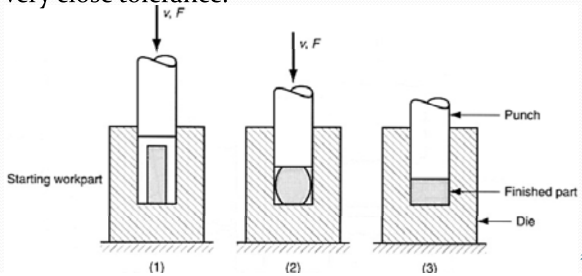
[10 – Marks]

211

For IES Only

Flashless forging

- The work material is completely surrounded by the die cavity during compression and no flash is formed.
- Most important requirement in flashless forging is that the work volume must equal the space in the die cavity to a very close tolerance.



212

IES – 2008

The balls of the ball bearings are manufactured from steel rods. The operations involved are:

1. Ground
2. Hot forged on hammers
3. Heat treated
4. Polished

What is the correct sequence of the above operations from start?

(a) 3-2-4-1 (b) 3-2-1-4

(c) 2-3-1-4 (d) 2-3-4-1

213

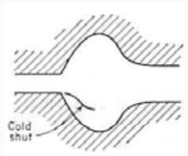
Lubrication for Forging

- Lubricants influence: friction, wear, deforming forces and flow of material in die-cavities, non-sticking, thermal barrier.
- For hot forging: graphite, MoS_2 and sometimes molten glass.
- For cold forging: mineral oil and soaps.
- In hot forging, the lubricant is applied to the dies, but in cold forging, it is applied to the workpiece.

214

Forging Defects

- **Unfilled Sections: D**ie cavity is not completely filled, due to improper design of die
- **Cold Shut or fold: A** small crack at the corners and at right angles to the forged surface. Cause: improper design of the die



Cold shut or fold

215

Forging Defects Contd….

- **Scale Pits: I**rregular depressions on the surface due to improper cleaning of the stock.
- **Die Shift:** Due to Misalignment of the two die halves or making the two halves of the forging to be of improper shape.
- **Flakes: I**nternal ruptures caused by the improper cooling.
- **Improper Grain Flow:** This is caused by the improper design of the die, which makes the flow of metal not flowing the final intended directions.

216

Forging Defects Contd….

- **Forging Laps:** These are folds of metal squeezed together during forging. They have irregular contours and occur at right angles to the direction of metal flow.
- **Hot tears and thermal cracking:** These are surface cracks occurring due to non-uniform cooling from the forging stage or during heat treatment.

217

IAS – 1998

The forging defect due to hindrance to smooth flow of metal in the component called 'Lap' occurs because

(a) The corner radius provided is too large
(b) The corner radius provided is too small
(c) Draft is not provided
(d) The shrinkage allowance is inadequate

218

IES 2011

Assertion (A) : Hot tears occur during forging because of inclusions in the blank material

Reason (R) : Bonding between the inclusions and the parent material is through physical and chemical bonding.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

219

GATE -2008 (PI)

Match the following

Group -1	Group-2
P . Wrinkling	1. Upsetting
Q. Centre burst	2. Deep drawing
R. Barrelling	3. Extrusion
S. Cold shut	4. Closed die forging

(a) P – 2, Q – 3, R – 4, S-1
(b) P – 3, Q – 4, R – 1, S-2
(c) P – 2, Q – 3, R – 1, S-4
(d) P – 2, Q – 4, R – 3, S-1

220

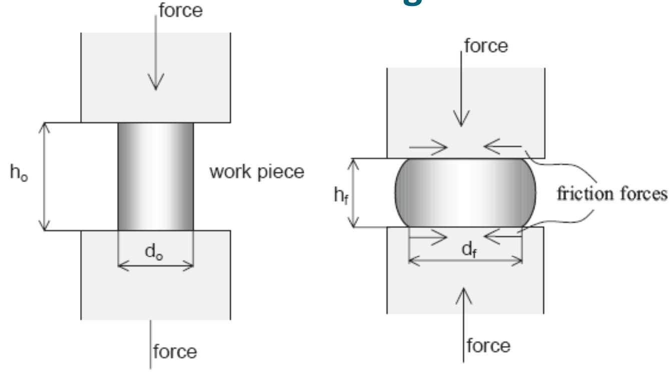
IES - 2007

Sometimes the parting plane between two forging dies is not a horizontal plane, give the main reason for this design aspect, why is parting plane provided, in closed die forging?

[2 marks]

221

Barrelling



Inhomogeneous deformation with barreling of the workpiece

222

IES-2013

Consider the following statements pertaining to the open-die forging of a cylindrical specimen between two flat dies:

1. Lubricated specimens show more surface movement than un-lubricated ones.
2. Lubricated specimens show less surface movement than un-lubricated ones.
3. Lubricated specimens show more barrelling than un-lubricated ones.
4. Lubricated specimens shows less barrelling than un-lubricated ones.

Which of these statements are correct?

(*a*) 1 and 3 (*b*) 1 and 4 (*c*) 2 and 3 (*d*) 2 and 4

223

Die Materials Should have

- Good hardness, toughness and ductility at low and elevated temperatures
- Adequate fatigue resistance
- Sufficient hardenability
- Low thermal conductivity
- Amenability to weld repair
- Good machinability

Material: Cr-Mo-V-alloyed tool steel and Cr-Ni-Mo-alloyed tool steel.

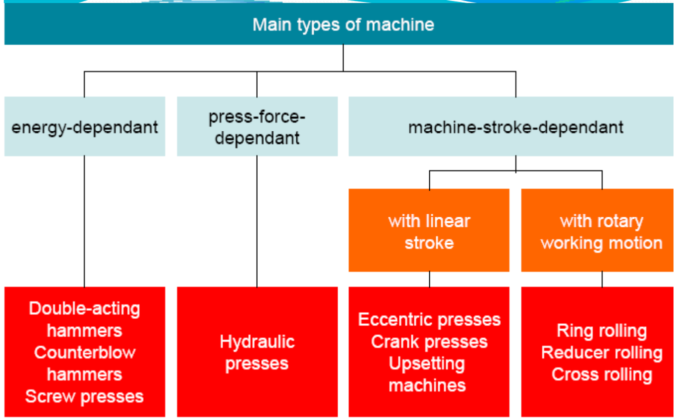
224

GATE -2010 (PI)

Hot die steel, used for large solid dies in drop forging, should necessarily have

(a) high strength and high copper content
(b) high hardness and low hardenability
(c) high toughness and low thermal conductivity
(d) high hardness and high thermal conductivity

225



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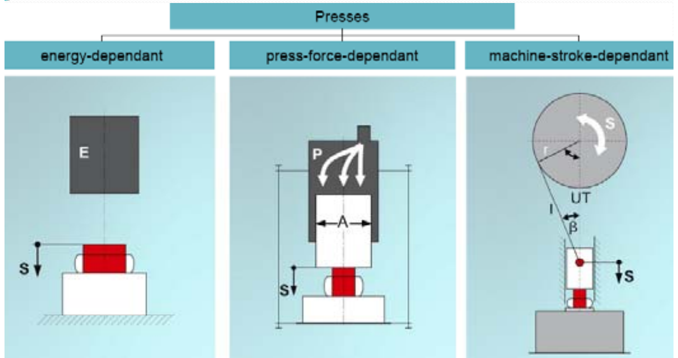


IES-2013

Statement (I): In power forging energy is provided by compressed air or oil pressure or gravity.

Statement (II): The capacity of the hammer is given by the total weight, which the falling pans weigh.

(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

True Stress & True Strain

$$\text{True stress}\,(\sigma_T) = \sigma(1+\varepsilon)$$

$$\text{True strain}\,(\varepsilon_T) = \ln(1+\varepsilon) = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{A_o}{A}\right) = 2\ln\left(\frac{d_o}{d}\right)$$

GATE-2014

The relationship between true strain (ε_T) and engineering strain (ε_E) in a uniaxial tension test is

(*a*) $\varepsilon_E = \ln(1 + \varepsilon_T)$ (*b*) $\varepsilon_E = \ln(1 - \varepsilon_T)$

(*c*) $\varepsilon_T = \ln(1 + \varepsilon_E)$ (*d*) $\varepsilon_T = \ln(1 - \varepsilon_E)$

GATE-1992, ISRO-2012, VS-2013

The true strain for a low carbon steel bar which is doubled in length by forging is

(a) 0.307

(b) 0.5

(c) 0.693

(d) 1.0

GATE-2016

Engineering strain of a mild steel sample is recorded as 0.100%. The true strain is

(a) 0.010 %

(b) 0.055 %

(c) 0.099 %

(d) 0.101 %

GATE-2007

In open-die forging, a disc of diameter 200 mm and height 60 mm is compressed without any barreling effect. The final diameter of the disc is 400 mm. The true strain is

(a) 1.986 (b) 1.686

(c) 1.386 (d) 0.602

GATE-2017 (PI)

A steel wire of 2 mm diameter is to be drawn from a wire of 5 mm diameter. The value of true strain developed is ____________(up to three decimal places).

GATE-2016

The value of true strain produced in compressing a cylinder to half its original length is

(a) 0.69 (b) -0.69

(c) 0.5 (d) -0.5

235

GATE-2018

A bar is compressed to half of its original length. The magnitude of true strain produced in the deformed bar is__________(correct to two decimal places).

236

GATE-2017

A rod of length 20 mm is stretched to make a rod of length 40 mm. Subsequently, it is compressed to make a rod of final length 10 mm. Consider the longitudinal tensile strain as positive and compressive strain as negative. The total true longitudinal strain in the rod is

(a) -0.5 (b) -0.69 (c) -0.75 (d) -1.0

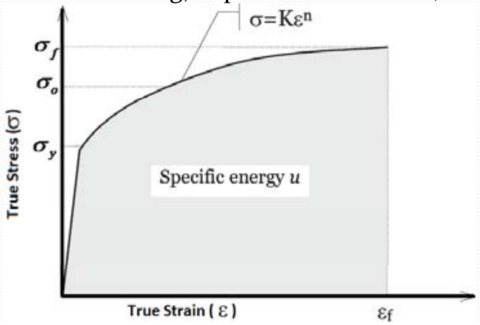
237

Strain Hardening & Flow Stress

- In the plastic region, the material behaviour is expressed by the flow curve:

$$\sigma = K\varepsilon^n$$

Where K is strength coefficient and n is strain-hardening (or work-hardening) exponent and at UTS, ε = n



238

GATE-2018

The true stress (in MPa) versus true strain relationship for a metal is given by, $\sigma = 1020 \times \varepsilon^{0.4}$. The cross-sectional area at the start of a test (when the stress and strain values are equal to zero) is 100 mm². The cross-sectional area at the time of necking (in mm²) is_______(correct to two decimal places).

239

Average Flow Stress

- Average (mean) flow stress is not on the basis of instantaneous flow stress, but on an average value over the stress – strain curve from the beginning of strain to the final (maximum) value that occurs during deformation.

$$\text{Average flow stress}\left(\bar{\sigma}_o\right) = \frac{K\varepsilon_f^n}{1+n}$$

Here ε_f is the maximum strain value during deformation.

240

Strain rate effects

- Strain rate effect (hot Working)

$$\sigma_o = C\dot{\varepsilon}$$

$$\dot{\varepsilon} = \frac{1}{h}\frac{dh}{dt} = \frac{v}{h} = \frac{\text{Platen Velocity}}{\text{Instantaneous height}}$$

241

GATE-2006

The ultimate tensile strength of a material is 400 MPa and the elongation up to maximum load is 35%. If the material obeys power law of hardening, then the true stress-true strain relation (stress in MPa) in the plastic deformation range is:

(a) $\sigma = 540\ \varepsilon^{0.30}$ (b) $\sigma = 775\ \varepsilon^{0.30}$

(c) $\sigma = 540\ \varepsilon^{0.35}$ (d) $\sigma = 775\ \varepsilon^{0.35}$

242

GATE-2015

The strain hardening exponent n of stainless steel SS 304 with distinct yield and UTS values undergoing plastic deformation is

a) n<0

b) n=0

c) 0<n<1

d) n=1

243

GATE-2017

The Poisson's ratio for a perfectly incompressible linear elastic material is

(a) 1 (b) 0.5

(c) 0 (d) Infinite

GATE-2012 Same Q GATE -2012 (PI)

A solid cylinder of diameter 100 mm and height 50 mm is forged between two frictionless flat dies to a height of 25 mm. The percentage change in diameter is

(a) 0 (b) 2.07 (c) 20.7 (d) 41.4

GATE-2016 (PI)

Two solid cylinders of equal diameter have different heights. They are compressed plastically by a pair of rigid dies to create the same percentage reduction in their respective heights. Consider that the die-workpiece interface friction is negligible. The ratio of the final diameter of the shorter cylinder to that of the longer cylinder is __________.

GATE-2015

The flow stress (in MPa) of a material is given by

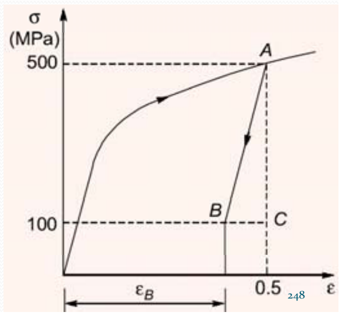
$$\sigma = 500\varepsilon^{0.1}$$

Where ε is true strain. The Young's modulus of elasticity of the material is 200 GPa. A block of thickness 100 mm made of this material is compressed to 95 mm thickness and then the load is removed. The final dimension of the block (in mm) is ________

GATE-2018

The true stress (σ), true strain (ε) diagram of a strain hardening material is shown in figure.

First, there is loading up to point A, i.e. up to stress of 500 MPa and strain of 0.5. then from point A, there is unloading up to point B, i.e. to stress of 100 MPa, Given that the Young's modulus E = 200 GPa, the natural strain at point B (ε_B) ________(correct to two decimal places).



GATE-2000 (PI)

A cylindrical billet of 100 mm diameter is forged from 50 mm height to 40 mm at 1000°C. The material has constant flow stress of 80 MPa. Find the work of deformation. If a 10 KN drop hammer is used to complete the reduction in one blow. What will be the height of fall?

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Assumption

- Forging force is maximum at the end of the forging.
- Coefficient of friction is constant between workpiece and dies (platens).
- Thickness of the workpiece is small compared with other dimensions, and the variation of stress field along y-direction is negligible.
- Length is much more than width, problem is plain strain type.
- The entire workpiece is in the plastic state during the process.

For IES Only

IES - 2012

Assumptions adopted in the analysis of open die forging are

1. Forging force attains maximum value at the middle of the operation.

2. Coefficient of friction is constant between work piece and die

2. Stress in the vertical (Y-direction) is zero.

(a) 1 and 2 (b) 1 and 3

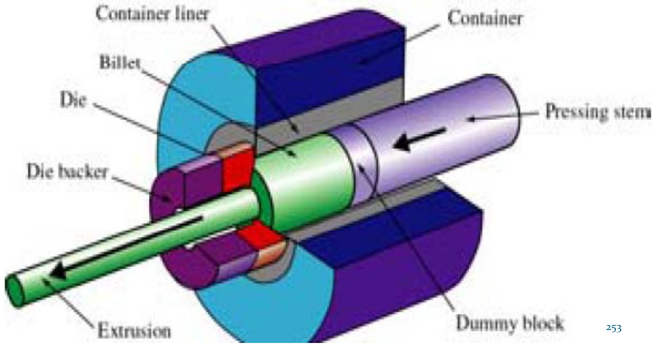
(c) 2 and 3 (d) 1, 2 and 3

Extrusion & Drawing

By S K Mondal

Extrusion

- The extrusion process is like squeezing toothpaste out of a tube.



253

- Metal is compressed and forced to flow through a suitably shaped die to form a product with reduced but constant cross section.
- Metal will undergo tri-axial compression.
- Hot extrusion is commonly employed.
- Lead, copper, aluminum, magnesium, and alloys of these metals are commonly extruded.

254

- Steels, stainless steels, and nickel-based alloys are difficult to extrude. (high yield strengths, welding with wall). Use **phosphate-based and molten glass lubricants .**

255

IES – 2007

Which one of the following is the correct statement?

(a) Extrusion is used for the manufacture of seamless tubes.

(b) Extrusion is used for reducing the diameter of round bars and tubes by rotating dies which open and close rapidly on the work?

(c) Extrusion is used to improve fatigue resistance of the metal by setting up compressive stresses on its surface

(d) Extrusion comprises pressing the metal inside a chamber to force it out by high pressure through an orifice which is shaped to provide the desired from of the finished part.

256

Extrusion Ratio

- Ratio of the cross-sectional area of the billet to the cross-sectional area of the product.
- about 40: 1 for hot extrusion of steel
- 400: 1 for aluminium

257

DRDO-2008

If the extrusion ratio is 20, the percentage reduction in the cross-sectional area of the billet after the extrusion will be

(a) 98% (b) 95% (c) 20% (d) 5%

258

Advantages of Extrusion

- Any cross-sectional shape can be extruded from the nonferrous metals.
- Many shapes (than rolling)
- No draft
- Huge reduction in cross section.
- Conversion from one product to another requires only a single die change
- Good dimensional precision.

259

IES - 2012

Extrusion process can effectively reduce the cost of product through

(a) Material saving

(b) process time saving

(c) Saving in tooling cost

(d) saving in administrative cost

260

IES – 2009

Which one of the following statements is correct?

(a) In extrusion process, thicker walls can be obtained by increasing the forming pressure

(b) Extrusion is an ideal process for obtaining rods from metal having poor density

(c) As compared to roll forming, extruding speed is high

(d) Impact extrusion is quite similar to Hooker's process including the flow of metal being in the same direction

261

Limitation of Extrusion

- Cross section must be uniform for the entire length of the product.

Application

- Working of poorly plastic and non ferrous metals and alloys.
- Manufacture of sections and pipes of complex configuration.
- Medium and small batch production.
- Manufacture of parts of high dimensional accuracy.

IES – 1994

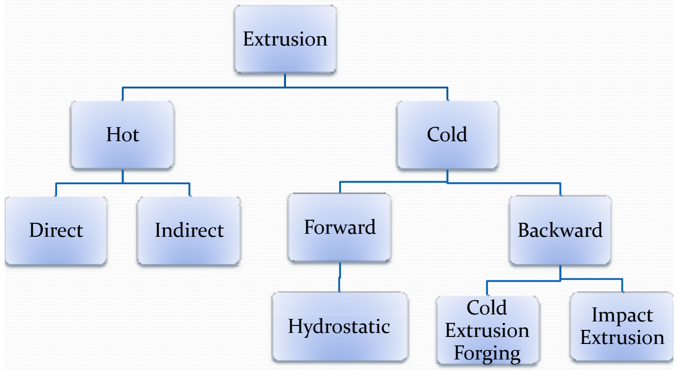
Metal extrusion process is generally used for producing

(a) Uniform solid sections
(b) Uniform hollow sections
(c) Uniform solid and hollow sections
(d) Varying solid and hollow sections.

GATE-1994

The process of hot extrusion is used to produce

(a) Curtain rods made of aluminium
(b) Steel pipes/or domestic water supply
(c) Stainless steel tubes used in furniture
(d) Large shape pipes used in city water mains



IES – 1999

Which one of the following is the correct temperature range for hot extrusion of aluminium?

(a) 300-340°C (b) 350-400°C
(c) 430-480°C (d) 550-650°C

IAS – 2012 main

Classify the process of extrusion with the help of sketches.

Hot Extrusion Process

- The temperature range for hot extrusion of aluminum is 430-480°C
- Used to produce curtain rods made of aluminum.
- Design of die is a problem.
- Either direct or indirect method used.

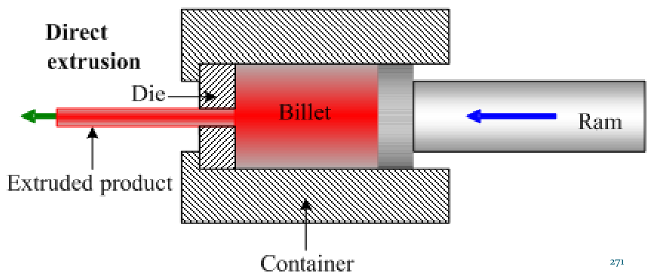
IES – 2009

What is the major problem in hot extrusion?

(a) Design of punch (b) Design of die
(c) Wear and tear of die (d) Wear of punch

Direct Extrusion

- A solid ram drives the entire billet to and through a stationary die and must provide additional power to overcome the frictional resistance between the surface of the moving billet and the confining chamber.



IES – 1993

Assertion (A): Direct extrusion requires larger force than indirect extrusion.

Reason (R): In indirect extrusion of cold steel, zinc phosphate coating is used.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES – 2000

Consider the following statements:

In forward extrusion process

1. The ram and the extruded product travel in the same direction.
2. The ram and the extruded product travel in the opposite direction.
3. The speed of travel of the extruded product is same as that of the ram.
4. The speed of travel of the extruded product is greater than that of the ram.

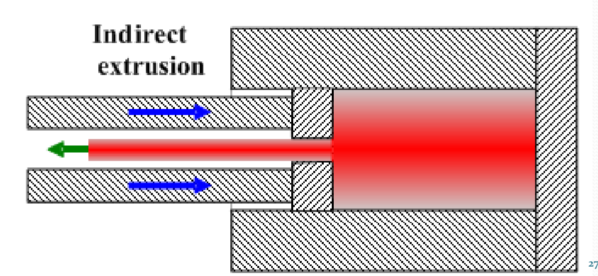
Which of these Statements are correct?

(a) 1 and 3 (b) 2 and 3

(c) 1 and 4 (d) 2 and 4

Indirect Extrusion

- A hollow ram drives the die back through a stationary, confined billet.
- Since no relative motion, friction between the billet and the chamber is eliminated.



Indirect Extrusion Contd...

- Required force is lower (25 to 30% less)
- Low process waste.

IES - 2012

Which of the following are correct for an indirect hot extrusion process?

1. Billet remains stationary

2. There is no friction force between billet and container walls.

3. The force required on the punch is more in comparison to direct extrusion.

4. Extrusion parts have to be provided a support.

(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only

(c) 1, 2 and 4 only (d) 2, 3 and 4 only

IES – 2007

Assertion (A): Greater force on the plunger is required in case of direct extrusion than indirect one.

Reason (R): In case of direct extrusion, the direction of the force applied on the plunger and the direction of the movement of the extruded metal are the same.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IAS – 2004

Assertion (A): Indirect extrusion operation can be performed either by moving ram or by moving the container.

Reason (R): Advantage in indirect extrusion is less quantity of scrap compared to direct extrusion.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES-2016

Statement (I): Employing the extrusion process is not economical in case of large billets.

Statement (II): A significant part of the press capacity is lost overcoming frictional resistance between workpiece and cylinder wall during the extrusion process.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true

Cold Extrusion

- Used with low-strength metals such as lead, tin, zinc, and aluminum to produce collapsible tubes for toothpaste, medications, and other creams; small "cans" for shielding electronic components and larger cans for food and beverages.
- **Now-a-days** also been used for forming mild steel parts.

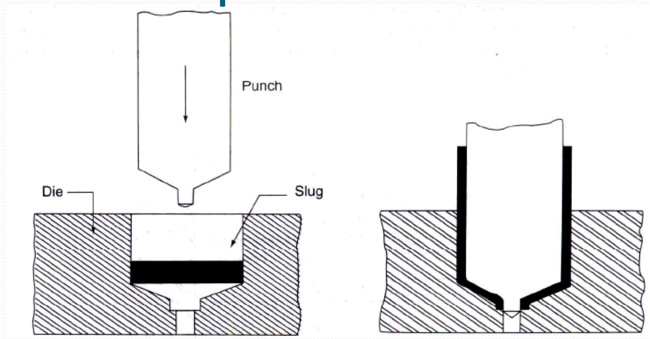
280

Backward cold extrusion

- The metal is extruded through the gap between the punch and die opposite to the punch movement.
- For softer materials such as aluminium and its alloys.
- Used for making collapsible tubes, cans for liquids and similar articles.

281

Impact Extrusion



- The extruded parts are stripped by the use of a stripper plate, because they tend to stick to the punch.

282

IES – 2008, GATE-1989(PI)

Which one of the following methods is used for the manufacture of collapsible tooth-paste tubes?

(a) Impact extrusion (b) Direct extrusion
(c) Deep drawing (d) Piercing

283

IES – 2003

The extrusion process (s) used for the production of toothpaste tube is/are

1. Tube extrusion
2. Forward extrusion
3. Impact extrusion

Select the correct answer using the codes given below:

Codes:

(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 3 only

284

IES - 2014

A toothpaste tube can be produced by
(a) Solid forward extrusion
(b) Solid backward extrusion
(c) Hollow backward extrusion
(d) Hollow forward extrusion

285

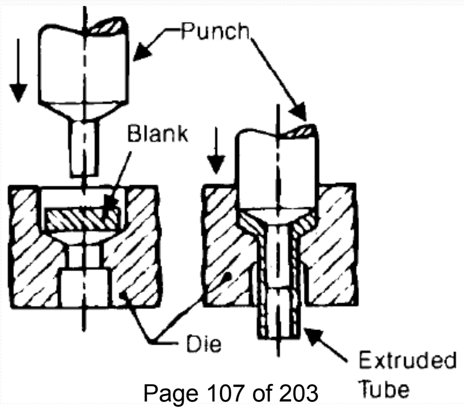
IAS-2010 Main

How are metal tooth-paste tubes made commercially ? Draw the tools configuration with the help of a neat sketch.

[30-Marks]

286

Hooker Method



287

Hooker Method

- The ram/punch has a shoulder and acts as a mandrel.
- A flat blank of specified diameter and thickness is placed in a suitable die and is forced through the opening of the die with the punch
- when the punch starts downward movement. Pressure is exerted by the shoulder of the punch, the metal being forced to flow through the restricted annular space between the punch and the opening in the bottom of the die.
- In place of a flat solid blank, a hollow slug can also be used.
- If the tube sticks to the punch on its upward stroke, a stripper will strip it from the punch.
- Small copper tubes and cartridge cases are extruded by this method.

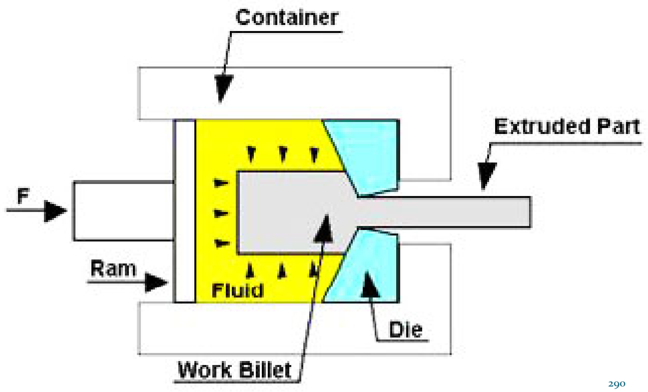
288

Hydrostatic Extrusion

- Another type of cold extrusion process.
- High-pressure fluid applies the force to the workpiece through a die.
- It is forward extrusion, but the fluid pressure surrounding the billet prevents upsetting.
- Billet-chamber friction is eliminated, and the pressurized fluid acts as a lubricant between the billet and the die.

289

Hydrostatic Extrusion Contd....



290

Hydrostatic Extrusion Contd....

- Temperature is limited since the fluid acts as a heat sink and the common fluids (light hydrocarbons and oils) burn or decomposes at moderately low temperatures.
- The metal deformation is performed in a high-compression environment. Crack formation is suppressed, leading to a phenomenon known as pressure-induced ductility.
- Relatively brittle materials like cast iron, stainless steel, *molybdenum, tungsten* and various inter-metallic compounds can be plastically deformed without fracture, and materials with limited ductility become highly plastic.

291

Application

- Extrusion of nuclear reactor fuel rod
- Cladding of metals
- Making wires for less ductile materials

292

IAS – 2000

Assertion (A): Brittle materials such as grey cast iron cannot be extruded by hydrostatic extrusion.

Reason(R): In hydrostatic extrusion, billet is uniformly compressed from all sides by the liquid.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

293

IES – 2006

What does hydrostatic pressure in extrusion process improve?

(a) Ductility (b) Compressive strength

(c) Brittleness (d) Tensile strength

294

GATE-1990(PI)

Semi brittle materials can be extruded by

(a) Impact extrusion

(b) Closed cavity extrusion

(c) Hydrostatic extrusion

(d) Backward extrusion

295

IES – 2001

Which of the following statements are the salient features of hydrostatic extrusion?

1. It is suitable for soft and ductile material.
2. It is suitable for high-strength super-alloys.
3. The billet is inserted into the extrusion chamber and pressure is applied by a ram to extrude the billet through the die.
4. The billet is inserted into the extrusion chamber where it is surrounded by a suitable liquid. The billet is extruded through the die by applying pressure to the liquid.

Select the correct answer using the codes given below:

Codes:

(a) 1 and 3 (b) 1 and 4

(c) 2 and 3 (d) 2 and 4

296

Lubrication for Extrusion

- For hot extrusion glass is an excellent lubricant with steels, stainless steels and high temperature metals and alloys.
- For cold extrusion, lubrication is critical, especially with steels, because of the possibility of sticking (seizure) between the workpiece and the tooling if the lubrication breaks down. Most effective lubricant is a phosphate conversion coating on the workpiece.

297

IES 2009 Conventional

Explain the processes of extrusion given below.

Indicate one typical product made through each of these processes:

(i) Direct Extrusion

(ii) Indirect Extrusion

(iii) Hydrostatic Extrusion

(iv) Impact Extrusion

Process variables in Extrusion

1. **Experimental studies of flow**
2. **Temperature and Metallurgy**: Variations in temperature during extrusion seem to influence flow behaviour in number of ways. As indicated, flow patterns may be changed considerably by rendering the temperature distribution in the container. It is known that the extrusion pressure may be lowered if either the temperature of the billet or the velocity of the stem is increased, and that there are certain limitations, because the material starts melting or cracking if it is leaves the die with too high temperature.

IES - 2014

Statement-I: For high extrusion pressure, the initial temperature of billet should be high.

Statement-II: As the speed of hot extrusion is increased, it may lead to melting of alloy constituents

(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

Extrusion Defects

- **Surface crack** due to high temperature, high speed, high friction etc.
- **Bamboo defects** at low temperature due to sticking of metals in die land.
- **Pipe defects or tail pipe or fishtailing**, during extrusion surface oxides and impurities are driven towards the centre of the billet, like funnel called pipe.
- **Centre Burst or Chevron defect** are attributed to a state of hydrostatic tensile stress at the centreline in the deformation zone in the die. Tendency increases with increasing die angle and amount of impurities. Tendency decrease with increasing extrusion ratio and friction.

GATE-2018 (PI)

Which one of the following defects is NOT associated with the casting process?

(a) Hot tear

(b) Porosity

(c) Blister

(d) Central burst

IES-2016

Surface cracking occurring at low temperature in hydrostatic extrusion is know as

(a) Fluid Defect (b) Bamboo Defect

(c) Fishtailing (d) Arrowhead Fracture

JWM 2010

Assertion (A) : Extrusion speed depends on work material.

Reason (R) : High extrusion speed causes cracks in the material.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IAS – 2012 main

Enumerate the conditions under which central burst may occur. Where does a 'pipe' occur ?

GATE-2014

With respect to metal working, match Group A with Group B

Group A	Group B
P: Defect in extrusion	I: alligatoring
Q: Defect in rolling	II: scab
R: Product of skew rolling	III: fish tail
S: Product of rolling through cluster mill	IV: seamless tube
	V: thin sheet with tight tolerance
	VI: semi-finished balls of ball bearing

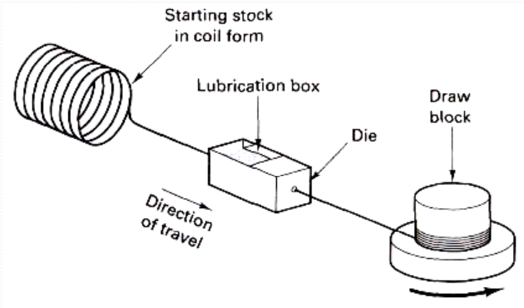
	P	Q	R	S		P	Q	R	S
(*a*)	II	III	VI	V	(*b*)	III	I	VI	V
(*c*)	III	I	IV	VI	(*d*)	I	II	V	VI

Wire Drawing

- A cold working process to obtain wires from rods of bigger diameters through a die.
- Same process as bar drawing except that it involves smaller-diameter material.
- At the start of wire drawing, the end of the rod or wire to be drawn is pointed to make for an easier entrance of wire into the die. This pointing is done by means of rotary swaging or by simple hammering.

307

Wire Drawing Contd….



308

Wire Drawing Contd….

- Wire getting continuously wound on the reel.
- For fine wire, the material may be passed through a number of dies, receiving successive reductions in diameter, before being coiled and known as Tandem Drawing.
- **The wire is subjected to tension only.** But when it is in contact with dies then a combination of tensile, compressive and shear stresses will be there in that portion only.
- Wire drawing is always a cold-working process, need sufficient ductility, may be annealed before drawing.

309

IES – 2007

Which metal forming process is used for manufacture of long steel wire?

(a) Deep drawing (b) Forging

(c) Drawing (d) Extrusion

310

IES – 2009

Which one of the following stress is involved in the wire drawing process?

(a) Compressive (b) Tensile

(c) Shear (d) Hydrostatic stress

311

IES – 2005

Which of the following types of stresses is/are involved in the wire-drawing operation?

(a) Tensile only

(b) Compressive only

(c) A combination of tensile and compressive stresses

(d) A combination of tensile, compressive and shear stresses

312

GATE-1987

For wire drawing operation, the work material should essentially be

(a) Ductile (b) Tough

(c) Hard (d) Malleable

313

IES-2016

Statement (I) : In wire-drawing, the end of the stock is made 'pointed' to make for easier entrance of the wire into the die.

Statement (II) : The pointing of the wire is done exclusively by rotary swaging and not by simple hammering.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true

314

Cleaning and Lubrication in wire Drawing

- Cleaning is done to remove scale and rust by ***acid pickling.***
- Lubrication boxes precede the individual dies to help reduce friction drag and prevent wear of the dies.
- **Sulling:** The wire is coated with a thin coat of ferrous hydroxide which when combined with lime acts as filler for the lubricant.
- ***Phosphating:*** A thin film of Mn, Fe or Zn phosphate is applied on the wire.
- **Electrolytic coating:** For very thin wires, electrolytic coating of copper is used to reduce friction.

315

IES 2010

Assertion (A): Pickling and washing of rolled rods is carried out before wire drawing.

Reason (R): They lubricate the surface to reduce friction while drawing wires.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IES – 2000

Which one of the following lubricants is most suitable for drawing mild steel wires?

(a) Sodium stearate (b) Water

(c) Lime-water (d) Kerosene

IAS – 1995

The following operations are performed while preparing the billets for extrusion process:

1. Alkaline cleaning
2. Phosphate coating
3. Pickling
4. Lubricating with reactive soap.

The correct sequence of these operations is

(a) 3, 1, 4, 2 (b) 1, 3, 2, 4

(c) 1, 3. 4, 2 (d) 3, 1, 2, 4

IES – 1996

In wire drawing process, the bright shining surface on the wire is obtained if one

(a) does not use a lubricant

(b) uses solid powdery lubricant.

(c) uses thick paste lubricant

(d) uses thin film lubricant

For IES Only

Bundle Drawing

In this process, many wires (as much as several thousand) are drawn simultaneously as a bundle. To prevent sticking, the wires are separated from each other by a suitable material. The cross-section of the wires is somewhat polygonal.

For IES Only

IES - 2014

Statement-I: In drawing process, cross-section of round wire is reduced by pulling it through a die

Statement-II: Bundle drawing produces wires that are polygonal in cross-section rather than round

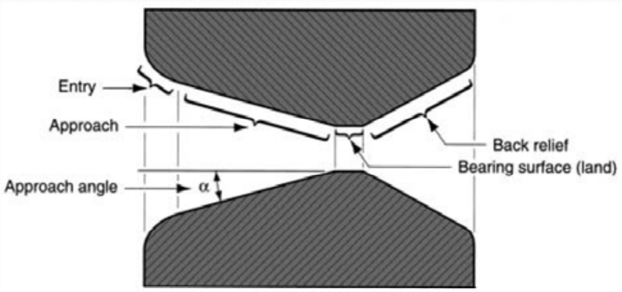
(*a*) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(*b*) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(*c*) Statement (I) is true but Statement (II) is false

(*d*) Statement (I) is false but Statement (II) is true

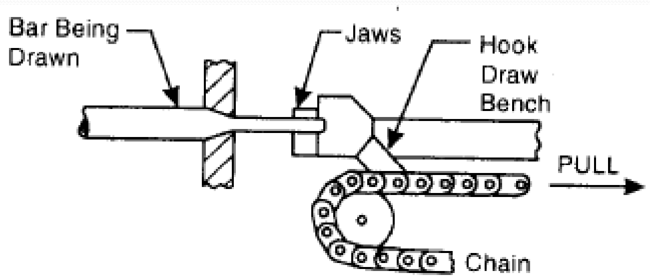
Wire Drawing Die



- **Die materials:** tool steels or tungsten carbides or polycrystalline diamond (for fine wire)

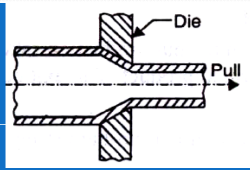
Rod and Tube Drawing

- Rod drawing is similar to wire drawing except for the fact that the dies are bigger because of the rod size being larger than the wire.
- The tubes are also first pointed and then entered through the die where the point is gripped in a similar way as the bar drawing and pulled through in the form desired along a straight line.
- When the final size is obtained, the tube may be annealed and straightened.
- The practice of drawing tubes without the help of an internal mandrel is called tube sinking.

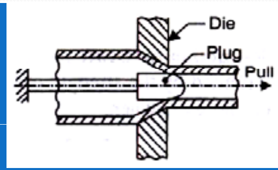


Back

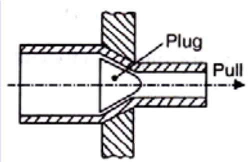
Rod and Tube Drawing Contd...



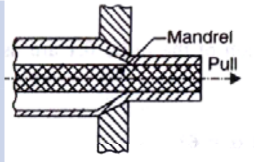
Tube Sinking



Fixed Plug Drawing



Floating plug Drawing



Moving Mandrel

IES-1993; GATE-1994(PI), 2014(PI)

A moving mandrel is used in

(a) Wire drawing (b) Tube drawing

(c) Metal Cutting (d) Forging

IAS-2006

Which one of the following processes necessarily requires mandrel of requisite diameter to form the internal hole?

(a) Hydrostatic Extrusion

(b) Tube drawing

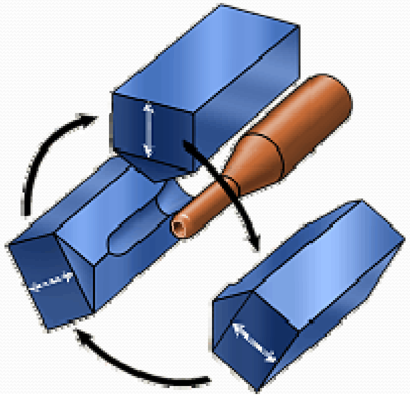
(c) Swaging

(d) Wire Drawing

Swaging or kneading

- The hammering of a rod or tube to reduce its diameter where the die itself acts as the hammer.
- Repeated blows are delivered from various angles, causing the metal to flow inward and assume the shape of the die.
- It is cold working. The term swaging is also applied to processes where material is forced into a confining die to reduce its diameter.

Swaging or kneading Contd...



IES-2015

Rotary swaging is a process for shaping

a) Round bars and tubes

b) Billets

c) Dies

d) Rectangular blocks

IES – 1993

Tandem drawing of wires and tubes is necessary because

(a) It is not possible to reduce at one stage

(b) Annealing is needed between stages

(c) Accuracy in dimensions is not possible otherwise

(d) Surface finish improves after every drawing stage

IES – 2000

Match List I (Components of a table fan) with List II (Manufacturing processes) and select the correct answer using the codes given below the Lists:

	List I		List II
A.	Base with stand	1.	Stamping and pressing
B.	Blade	2.	Wire drawing
C.	Armature coil wire	3.	Turning
D.	Armature shaft	4.	Casting

Codes:	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	2	1	4	3
(c)	2	3	4	1	(d)	4	1	2	3

IES – 1999

Match List-I with List-II and select the correct answer using the codes given below the Lists:

	List-I		List-II
A.	Drawing	1.	Soap solution
B.	Rolling	2.	Camber
C.	Wire drawing	3.	Pilots
D.	Sheet metal operations using progressive dies	4.	Crater
		5.	Ironing

Code:	A	B	C	D		A	B	C	D
(a)	2	5	1	4	(b)	4	1	5	3
(c)	5	2	3	4	(d)	5	2	1	3

IES – 1996

Match List I with List II and select the correct answer

List I (Metal/forming process)		List II (Associated force)
A. Wire drawing	1.	Shear force
B. Extrusion	2.	Tensile force
C. Blanking	3.	Compressive force
D. Bending	4.	Spring back force

Codes:	A	B	C	D		A	B	C	D
(a)	4	2	1	3	(b)	2	1	3	4
(c)	2	3	1	4	(d)	4	3	2	1

334

IES – 1994

Match List I with List II and select the correct answer using the codes given below the Lists:

List I (Metal farming process)		List II (A similar process)
A. Blanking	1.	Wire drawing
B. Coining	2.	Piercing
C. Extrusion	3.	Embossing
D. Cup drawing	4.	Rolling
	5.	Bending

Codes:	A	B	C	D		A	B	C	D
(a)	2	3	4	1	(b)	2	3	1	4
(c)	3	2	1	5	(d)	2	3	1	5

335

IES – 1993, ISRO-2010

Match List I with List II and select the correct answer using the codes given below the lists:

List I (Mechanical property)		List II (Related to)
A. Malleability	1.	Wire drawing
B. Hardness	2.	Impact loads
C. Resilience	3.	Cold rolling
D. Isotropy	4.	Indentation
	5.	Direction

Codes:	A	B	C	D		A	B	C	D
(a)	4	2	1	3	(b)	3	4	2	5
(c)	5	4	2	3	(d)	3	2	1	5

336

IES – 2002

Match List I with List II and select the correct answer:

List I (Parts)		List II (Manufacturing processes)
A. Seamless tubes	1.	Roll forming
B. Accurate and smooth tubes	2.	Shot peening
C. Surfaces having higher hardness and fatigue strength	3.	Forging
	4.	Cold forming

Codes:	A	B	C		A	B	C
(a)	1	4	2	(b)	2	3	1
(c)	1	3	2	(d)	2	4	1

337

IAS – 2001

Match List I (Products) with List II (Suitable processes) and select the correct answer using the codes given below the Lists:

List I		List II
A. Connecting rods	1.	Welding
B. Pressure vessels	2.	Extrusion
C. Machine tool beds	3.	Forging
D. Collapsible tubes	4.	Casting

Codes:	A	B	C	D		A	B	C	D
(a)	3	1	4	2	(b)	4	1	3	2
(c)	3	2	4	1	(d)	4	2	3	1

338

GATE-2015

Match the following products with preferred manufacturing processes:

	Product		Process
P	Rails	1	Blow molding
Q	Engine Crankshaft	2	Extrusion
R	Aluminium Channels	3	Forging
S	PET water bottles	4	Rolling

a) P-4, Q-3, R-1, S-2 b) P-4, Q-3, R-2, S-1
c) P-2, Q-4, R-3, S-1 d) P-3, Q-4, R-2, S-1

339

IAS – 2002

Assertion (A): In wire-drawing process, the rod cross-section is reduced gradually by drawing it several times in successively reduced diameter dies.

Reason (R): Since each drawing reduces ductility of the wire, so after final drawing the wire is normalized.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

340

IES 2011

Match List –I with List –II and select the correct answer using the code given below the lists :

List –I	List –II
A. Connecting rods	1. Welding
B. Pressure vessels	2. Extrusion
C. Machine tool beds	3. Forming
D. Collapsible tubes	4. Casting

	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	3	1	4	2
(c)	2	4	1	3	(d)	3	4	1	2

341

GATE-2018

Match the following products with the suitable manufacturing process

	Product		Manufacturing Process
P	Toothpaste tube	1	Centrifugal casting
Q	Metallic pipes	2	Blow moulding
R	Plastic bottles	3	Rolling
S	Threaded bolts	4	Impact extrusion

(a) P-4, Q-3, R-1, S-2 (b) P-2, Q-1, R-3, S-4
(c) P-4, Q-1, R-2, S-3 (d) P-1, Q-3, R-4, S-2

342

Seamless tube Manufacturing

1. Rolling
2 Extrusion
3. Tube Drawing
4. Spinning

343

GATE-1991(PI)

Seamless long steel tubes are manufactured by rolling, drawing and

344

IAS 1994

Which of the following methods can be used for manufacturing 2 meter long seamless metallic tubes?

1. Drawing **2. Extrusion**
3. Rolling **4. Spinning**

Select the correct answer using the codes given below

Codes:

(a) 1 and 3 (b) 2 and 3
(c) 1, 3 and 4 (d) 2, 3 and 4

345

IES-2012 Conventional

How are the seamless tubes produced ?

346

Extrusion Load

- Approximate method (Uniform deformation, no friction) "work – formula"

$$P = A_o\sigma_o \ln\left(\frac{A_o}{A_f}\right) = 2\times\frac{\pi d_o^2}{4}\times\sigma_o\times\ln\left(\frac{d_o}{d_f}\right) = \frac{\pi d_o^2}{4}\times\sigma_o\times\ln(R)$$

- For real conditions

$$P = KA_o \ln\left(\frac{A_o}{A_f}\right) = 2\times\frac{\pi d_o^2}{4}\times K\times\ln\left(\frac{d_o}{d_f}\right)$$

K = extrusion constant.

347

Extrusion Stress

- Approximate method (Uniform deformation, no friction) "work – formula"

$$\sigma_E = \frac{P}{A_0} = \sigma_o \ln\left(\frac{A_o}{A_f}\right) = 2\times\sigma_o\times\ln\left(\frac{d_o}{d_f}\right) = \sigma_o\times\ln(R)$$

- For real conditions

$$\sigma_E = \frac{P}{A_0} = K\ln\left(\frac{A_o}{A_f}\right) = 2\times K\times\ln\left(\frac{d_o}{d_f}\right)$$

K = extrusion constant.

348

Force required in Wire or Tube drawing

- Approximate method (Uniform deformation, no friction) "work – formula"

$$P = A_f\sigma_o \ln\left(\frac{A_o}{A_f}\right) = 2\times\frac{\pi d_f^2}{4}\times\sigma_o\times\ln\left(\frac{d_o}{d_f}\right)$$

Drawing Stress

$$\sigma_d = \frac{P}{A_f} = \sigma_o \ln\left(\frac{A_o}{A_f}\right) = 2\times\sigma_o\times\ln\left(\frac{d_o}{d_f}\right)$$

349

GATE-2003

A brass billet is to be extruded from its initial diameter of 100 mm to a final diameter of 50 mm. The working temperature of 700°C and the extrusion constant is 250 MPa. The force required for extrusion is

(a) 5.44 MN (b) 2.72 MN
(c) 1.36 MN (d) 0.36 MN

350

GATE – 2009 (PI)

Using direct extrusion process, a round billet of 100 mm length and 50 mm diameter is extruded. Considering an ideal deformation process (no friction and no redundant work), extrusion ratio 4, and average flow stress of material 300 MPa, the pressure (in MPa) on the ram will be

(a) 416 (b) 624 (c) 700 (d) 832

351

GATE-2006

In a wire drawing operation, diameter of a steel wire is reduced from 10 mm to 8 mm. The mean flow stress of the material is 400 MPa. The ideal force required for drawing (ignoring friction and redundant work) is

(a) 4.48 kN (b) 8.97 kN

(c) 20.11 kN (d) 31.41 kN

352

GATE -2008 (PI) Linked S-1

A 10 mm diameter annealed steel wire is drawn through a die at a speed of 0.5 m/s to reduce the diameter by 20%. The yield stress of the material is 800 MPa.

Neglecting friction and strain hardening, the stress required for drawing (in MPa) is

(a) 178.5 (b) 357.0 (c) 1287.5 (d) 2575.0

353

GATE -2008 (PI) Linked S-2

A 10 mm diameter annealed steel wire is drawn through a die at a speed of 0.5 m/s to reduce the diameter by 20%. The yield stress of the material is 800 MPa.

The power required for the drawing process (in kW) is

(a) 8.97 (b) 14.0 (c) 17.95 (d) 28.0

354

IES-2014 Conventional

(i) What kind of products are manufactured by wire drawing process?

(ii) How much force will approximately be required to draw a wire from 1.5 mm diameter steel wire to 1.0 mm diameter wire if the average yield strength of the work material is 300 MPa?

[10 Marks]

355

GATE-2001, GATE -2007 (PI)

For rigid perfectly-plastic work material, negligible interface friction and no redundant work, the theoretically maximum possible reduction in the wire drawing operation is

(a) 0.36 (b) 0.63

(c) 1.00 (d) 2.72

356

GATE-2018

The maximum reduction in cross-sectional area per pass (R) of a cold wire drawing process is $R = 1 - e^{-(n+1)}$ where n represents the strain hardening co-efficient. For the case of a perfectly plastic material, R is

(a) 0.865 (b) 0.826 (c) 0.777 (d) 0.632

357

IES - 2014

In wire-drawing operation, the maximum reduction per pass for perfectly plastic material in ideal condition is

(a) 68 % (b) 63 %

(c) 58 % (d) 50%

358

GATE-1996

A wire of 0.1 mm diameter is drawn from a rod of 15 mm diameter. Dies giving reductions of 20%, 40% and 80% are available. For minimum error in the final size, the number of stages and reduction at each stage respectively would be

(a) 3 stages and 80% reduction for all three stages

(b) 4 stages and 80% reduction for first three stages followed by a finishing stage of 20% reduction

(c) 5 stages and reduction of 80%, 80%.40%, 40%, 20% in a sequence

(d) none of the above

359

GATE-2015

In a two stage wire drawing operation , the fractional reduction (ratio of change in cross – sectional area to initial cross-sectional area) in the first stage is 0.4. The fractional reduction in the second stage is 0.3. The overall fractional reduction is _____

(a) 0.24 (b) 0.58 (c) 0.60 (d) 1.0

360

GATE-2018 (PI)

In a two-pass wire drawing process, there is a 40% reduction in wire cross-sectional area in 1st pass and further 30% reduction in 2nd pass. The overall reduction (in percentage) is ______

361

Wire Drawing

$$\sigma_d = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_f}{r_o}\right)^{2B}\right]+\left(\frac{r_f}{r_o}\right)^{2B}.\sigma_b$$

σ_0 = yield strength of metarial

B = $\mu \cot \alpha$

μ = co-efficient of friction

α = half die-angle

r_f = radius of work piece at exist

r_0 = raidus of work piece at entry.

362

Maximum Reduction per pass

With back stress, σ_b

$$\sigma_o = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_{f\min}}{r_o}\right)^{2B}\right]+\left(\frac{r_{f\min}}{r_o}\right)^{2B}.\sigma_b$$

Without back stress, σ_b

$$\sigma_o = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_{f\min}}{r_o}\right)^{2B}\right]$$

363

IES – 2011 Conventional

A 12.5 mm diameter rod is to be reduced to 10 mm diameter by drawing in a single pass at a speed of 100 m/min. Assuming a semi die angle of 5° and coefficient of friction between the die and steel rod as 0.15, calculate:

(i) The power required in drawing

(ii) Maximum possible reduction in diameter of the rod

(iii) If the rod is subjected to a back pressure of 50 N/mm² , what would be the draw stress and maximum possible reduction ?

Take stress of the work material as 400 N/mm² .

[15 Marks]

364

GATE-2018

A steel wire is drawn from an initial diameter (d_i) of 10 mm to a final diameter (d_f) of 7.5 mm. The half cone angle (α) of the die is 5° and the coefficient of friction (μ) between the die and the wire is 0.1. The average of the initial and final yield stress [$(\sigma_y)_{avg}$] is 350 MPa. The equation for drawing stress σ_f (in MPa) is given as:

$$\sigma_f = (\sigma_y)_{avg}\left\{1+\frac{1}{\mu\cot\alpha}\right\}\left[1-\left(\frac{d_f}{d_i}\right)^{2\mu\cot\alpha}\right]$$

The drawing stress (in MPa) required to carry out this operation is________ (correct to two decimal places).

365

IFS-2016

A round rod of annealed brass 70-30 is being drawn from a diameter of 6 mm to 3 mm at a speed of 0.6 m/s. Assume that the frictional and redundant work together constitutes 35% of the ideal work of deformation.

Calculate (i) power required in this operation and (ii) die pressure at the exit of the die. [10-Marks]

Hint: K =895 MPa and n = 0.49

366

GATE – 2011 (PI) Common Data-S1

In a multi-pass drawing operation, a round bar of 10 mm diameter and 100 mm length is reduced in cross-section by drawing it successively through a series of seven dies of decreasing exit diameter. During each of these drawing operations, the reduction in cross-sectional area is 35%. The yield strength of the material is 200 MPa. Ignore strain hardening.

The total true strain applied and the final length (in mm), respectively, are

(a) 2.45 and 8 17 (b) 2.45 and 345

(c) 3.02 and 2043 (d) 3.02 and 3330

367

GATE – 2011 (PI) Common Data-S2

In a multi-pass drawing operation, a round bar of 10 mm diameter and 100 mm length is reduced in cross-section by drawing it successively through a series of seven dies of decreasing exit diameter. During each of these drawing operations, the reduction in cross-sectional area is 35%. The yield strength of the material is 200 MPa. Ignore strain hardening.

Neglecting friction and redundant work, the force (in kN) required for drawing the bar through the first die, is

(a) 15.71 (b) 10.21

(c) 6.77 (d) 4.39

368

GATE – 2014

A metal rod of initial length is subjected to a drawing process. The length of the rod at any instant is given by the expression, L(*t*) = $L_o(1 + t^2)$ where *t* is the time in minutes. The true strain rate at the end of one minute is ....

369

IAS – 1997

Extrusion force DOES NOT depend upon the

(a) Extrusion ratio
(b) Type of extrusion process
(c) Material of the die
(d) Working temperature

370

IES – 2012

Write the process variables in wire drawing.

Ans.

1. Reduction in cross sectional area
2. Die angle
3. Friction

371

The Degree of Drawing or Reduction factor in Cross Sectional area

$$D = \frac{A_o - A_f}{A_o} = \frac{D_o^2 - D_f^2}{D_o^2}$$

$$Therefore\ True\ strain(\varepsilon) = \ln\left(\frac{A_o}{A_f}\right) = \ln\left(\frac{1}{1-D}\right)$$

372

IAS – 2006

In drawing operation if D_i = initial diameter and D_o = Outgoing diameter, then what is the degree of drawing equal to?

(a) $\frac{D_i - D_o}{D_i}$ (b) $\frac{D_o - D_i}{D_o}$ (c) $\frac{D_i^2 - D_o^2}{D_i^2}$ (d) $\sqrt{\frac{D_i^2 - D_o^2}{D_i^2}}$

373

374

375

376

377

378

Sheet Metal

- Product has light weight and versatile shape as compared to forging/casting
- Most commonly used – low carbon steel sheet (cost, strength, formability)
- Aluminium and titanium for aircraft and aerospace
- Sheet metal has become a significant material for,
  - automotive bodies and frames,
  - office furniture
  - frames for home appliances

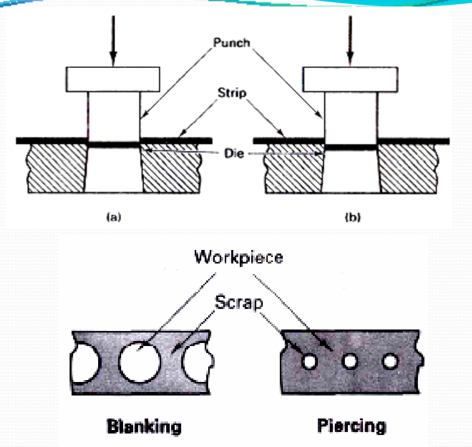
380

Piercing (Punching) and Blanking

- Piercing and blanking are shearing operations.
- **In blanking, the piece being punched out becomes the workpiece and any major burrs or undesirable features should be left on the remaining strip.**
- **In piercing (Punching), the punch-out is the scrap and the remaining strip is the workpiece.**
- Both done on some form of mechanical press.

381

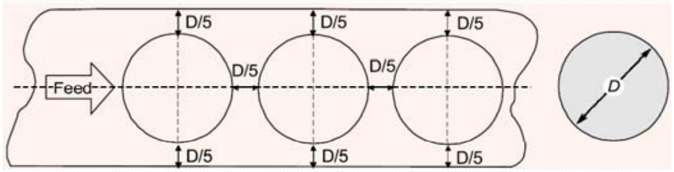
Piercing (Punching) and Blanking



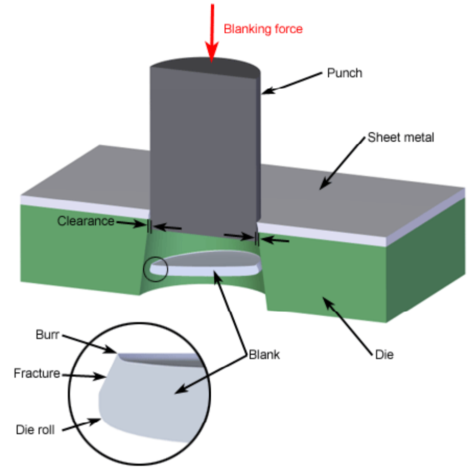
382

GATE-2018

The percentage scrap in a sheet metal blanking operation of a continuous strip of sheet metal as shown in the figure________(correct to two decimal places)



383

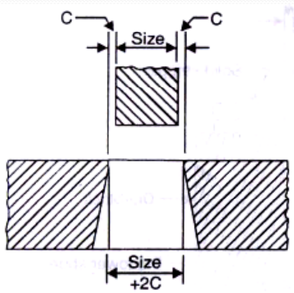


384

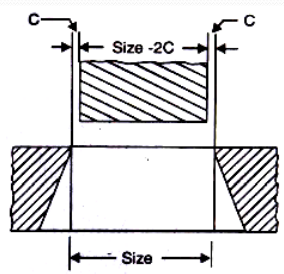
Clearance (VIMP)

- Die opening must be larger than punch and known as 'clearance'.
- **Punching**
  - Punch = size of hole
  - Die = punch size +2 clearance
  - **Remember:** In punching punch is correct size.
- **Blanking**
  - Die = size of product
  - Punch = Die size -2 clearance
  - **Remember:** In blanking die size will be correct.
- **Note: In punching clearance is provided on Die**
  In Blanking clearance is provided on punch

385



Punching



Blanking

386

Clearance

Contd….

- **The clearance is determined with following equation**

$$C = 0.0032t\sqrt{\tau}$$

- **Where τ is the shear strength of the material in N/mm²(MPa)**
- **Total clearance between punch and die size will be twice these 'C' i.e. 2C**

387

Clearance in %

- If the allowance for the material is a = 0.075 given then

  C = 0.075 x thickness of the sheet

- If clearance is 1% given then

  C = 0.01 x thickness of the sheet

Example

Determine the die and punch sizes for blanking a circular disc of 20-mm diameter from a sheet whose thickness is 1.5 mm.

Shear strength of sheet material = 294 MPa

Also determine the die and punch sizes for punching a circular hole of 20-mm diameter from a sheet whose thickness is 1.5 mm.

GATE-2003

A metal disc of 20 mm diameter is to be punched from a sheet of 2 mm thickness. The punch and the die clearance is 3%. The required punch diameter is

(a) 19.88 mm (b) 19.94 mm

(c) 20.06 mm (d) 20.12 mm

Punching Force and Blanking Force

$$F_{max} = Lt\tau$$

The punching force for holes which are smaller than the stock thickness may be estimated as follows:

$$F_{max} = \frac{\pi d t \sigma}{\sqrt[3]{\frac{d}{t}}}$$

Capacity of Press for Punching and Blanking

Press capacity will be = $F_{max} \times C$

[Where C is a constant and equal to 1.1 to 1.75 depending upon the profile]

Example

Estimate the blanking force to cut a blank 25 mm wide and 30 mm long from a 1.5 mm thick metal strip, if the ultimate shear strength of the material is 450 N/mm². Also determine the work done if the percentage penetration is 25 percent of material thickness.

GATE-2014

A rectangular hole of size 100 mm × 50 mm is to be made on a 5 mm thick sheet of steel having ultimate tensile strength and shear strength of 500 MPa and 300 MPa, respectively. The hole is made by punching process. Neglecting the effect of clearance, the punching force (in kN) is

(*a*) 300 (*b*) 450

(*c*) 600 (*d*) 750

IAS-2011 Main

For punching a 10 mm circular hole, and cutting a rectangular blank of 50 x 200 mm from a sheet of 1 mm thickness (mild steel, shear stress = 240 N/mm²), Calculate, in each case :

(i) Size of punch

(ii) Size of die

(iii) Force required. [10-Marks]

GATE-2016 (PI)

The ratio of press force required to punch a square hole of 30 mm side in a 1 mm thick aluminium sheet to that needed to punch a square hole of 60 mm side in a 2 mm thick aluminium sheet is_______________

Minimum Diameter of Piercing

Piercing pressure, $\tau_s \pi d.t$ = Strength of punch, $\sigma_c \times \frac{\pi}{4} d^2$

IES – 1999

A hole is to be punched in a 15 mm thick plate having ultimate shear strength of 3N-mm^{-2}. If the allowable crushing stress in the punch is 6 N-mm^{-2}, the diameter of the smallest hole which can be punched is equal to

(a) 15 mm (b) 30 mm

(c) 60 mm (d) 120 mm

IES - 2014

A hole of diameter 35 mm is to be punched in a sheet metal of thickness t and ultimate shear strength 400 MPa, using punching force of 44 kN. The maximum value of t is

(a) 0.5 mm

(b) 10 mm

(c) 1 mm

(d) 2 mm

ISRO-2008, 2011

With a punch for which the maximum crushing stress is 4 times the maximum shearing stress of the plate, the biggest hole that can be punched in the plate would be of diameter equal to

(a) $\frac{1}{4} \times$ Thickness of plate

(b) $\frac{1}{2} \times$ Thickness of plate

(c) Plate thickness

(d) 2 × Plate thickness

IES-2013

A hole of diameter *d* is to be punched in a plate of thickness *t*. For the plate material, the maximum crushing stress is 4 times the maximum allowable shearing stress. For punching the biggest hole, the ratio of diameter of hole to plate thickness should be equal to:

(*a*) $\frac{1}{4}$ **(*b*)** $\frac{1}{2}$

(*c*) 1 **(*d*) 2**

Energy and Power for Punching and Blanking

Ideal Energy (E in J)= maximum force x punch travel $= F_{max} \times (p \times t)$

(Unit: F_{max} in kN and t in mm othrwise use F_{max} in N and t in m)

Where p is percentage penetration required for rupture

$$Ideal\ power\ in\ press\ (P\ in\ W) = \frac{E \times N}{60}$$

[Where N = actual number of stroke per minute]

$$Actual\ Energy\ (E\ in\ J) = F_{max} \times (p \times t) \times C$$

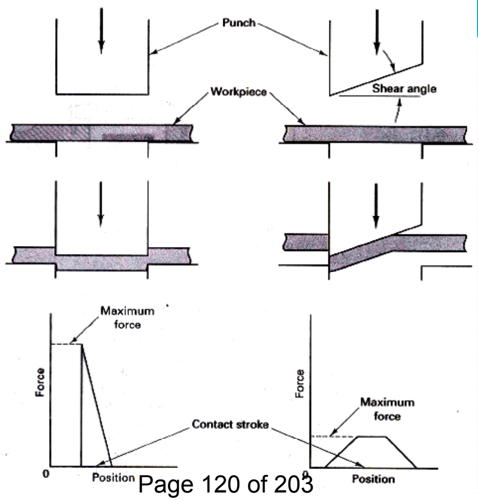
Where C is a constant and equal to 1.1 to 1.75 depending upon the profile

$$Actual\ power\ in\ press\ (P\ in\ W) = \frac{E \times N}{60 \times \eta}$$

WhereE is actual energy and η is efficiency of the press

Shear on Punch

- To reduce shearing force, shear is ground on the face of the die or punch.
- It distribute the cutting action over a period of time.
- Shear only reduces the maximum force to be applied but total work done remains same.



Force required with shear on Punch

$$F = \frac{F_{max} \times pt}{S + pt}$$ [for circular hole and other searing operations]

$$F = \frac{F_{max} \times pt}{S}$$ [For Shear cutting, or if force Vs displacement curve trapezoidal mentioned in the question.]

Where p = penetration of punch as a fraction

S = shear on the punch or die, mm

Example

- A hole, 100 mm diameter, is to be punched in steel plate 5.6 mm thick. The ultimate shear stress is 550 N/mm² . With normal clearance on the tools, cutting is complete at 40 per cent penetration of the punch. Give suitable shear angle for the punch to bring the work within the capacity of a 30T press.

Example

A washer with a 12.7 mm internal hole and an outside diameter of 25.4 mm is to be made from 1.5 mm thick strip. The ultimate shearing strength of the material of the washer is 280 N/mm².

(a) Find the total cutting force if both punches act at the same time and no shear is applied to either punch or the die.

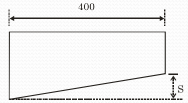
(b) What will be the cutting force if the punches are staggered, so that only one punch acts at a time.

(c) Taking 60% penetration and shear on punch of 1 mm, what will be the cutting force if both punches act together.

GATE-2010 Statement Linked 1

Statement for Linked Answer Questions:

In a shear cutting operation, a sheet of 5 mm thickness is cut along a length of 200 mm. The cutting blade is 400 mm long and zero-shear (S = 0) is provided on the edge. The ultimate shear strength of the sheet is 100 MPa and penetration to thickness ratio is 0.2. Neglect friction.



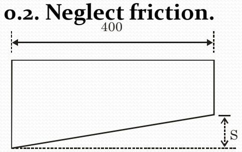
Assuming force vs displacement curve to be rectangular, the work done (in J) is

(a) 100 (b) 200 (c) 250 (d) 300

GATE-2010 Statement Linked 2

Statement for Linked Answer Questions:

In a shear cutting operation, a sheet of 5mm thickness is cut along a length of 200 mm. The cutting blade is 400 mm long and zero-shear (S = 0) is provided on the edge. The ultimate shear strength of the sheet is 100 MPa and penetration to thickness ratio is 0.2. Neglect friction.

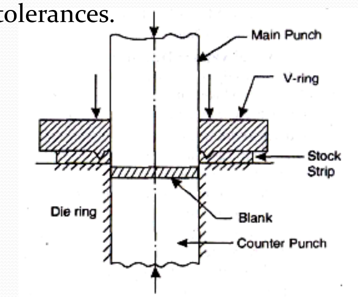


A shear of 20 mm (S = 20 mm) is now provided on the blade. Assuming force vs displacement curve to be trapezoidal, the maximum force (in kN) exerted is

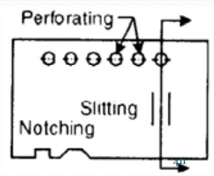
(a) 5 (b) 10 (c) 20 (d) 40

Fine Blanking

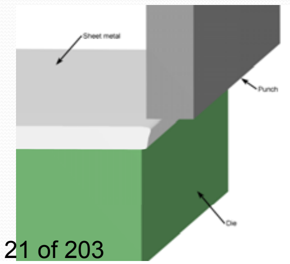
Fine Blanking - dies are designed that have small clearances and pressure pads that hold the material while it is sheared. The final result is blanks that have extremely close tolerances.



- **Slitting** - moving rollers trace out complex paths during cutting (like a can opener).
- **Perforating: M**ultiple holes which are very small and close together are cut in flat work material.
- **Notching:** Metal pieces are cut from the edge of a sheet, strip or blank.



- **Trimming** - Cutting unwanted excess material from the periphery of a previously formed component.
- **Shaving** - Accurate dimensions of the part are obtained by removing a thin strip of metal along the edges.



- **Lancing** – **A** hole is partially cut and then one side is bent down to form a sort of tab or louver. No metal removal, no scrap.

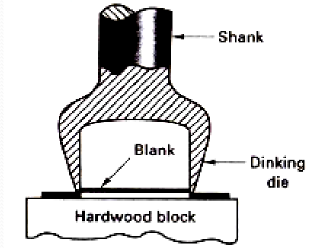
- **Squeezing** - Metal is caused to flow to all portions of a die cavity under the action of compressive forces.

- **Steel Rules** - soft materials are cut with a steel strip shaped so that the edge is the pattern to be cut.
- **Nibbling** - a single punch is moved up and down rapidly, each time cutting off a small amount of material. This allows a simple die to cut complex slots.

415

Dinking

- Used to blank shapes from low-strength materials, such as rubber, fiber, or cloth.
- The shank of a die is either struck with a hammer or mallet or the entire die is driven downward by some form of mechanical press.



416

Elastic recovery or spring back

- Total deformation = elastic deformation + plastic deformation.
- At the end of a metal working operation, when the pressure is released, there is an elastic recovery and the total deformation will get reduced a little. This phenomenon is called as "spring back".

417

Elastic recovery or spring back Contd..

- More important in cold working.
- It depends on the yield strength. Higher the yield strength, greater spring back.
- To compensate this, the cold deformation be carried beyond the desired limit by an amount equal to the spring back.

418

IAS – 2003

The 'spring back' effect in press working is

(a) Elastic recovery of the sheet metal after removal of the load
(b) Regaining the original shape of the sheet metal
(c) Release of stored energy in the sheet metal
(d) Partial recovery of the sheet metal

419

ISRO– 2013

Spring back in metal forming depends on

(a) Modulus of Elasticity
(b) Load Applied
(c) Strain Rate
(d) None of these

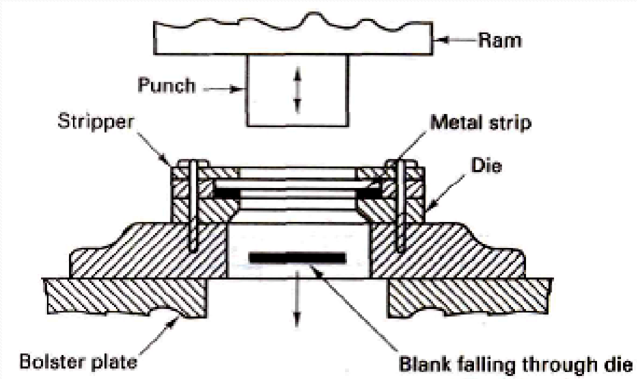
420

Punch and Die material

- Commonly used – tool steel
- For high production - carbides

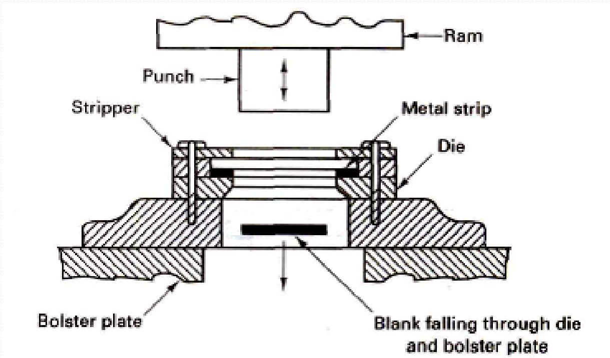
421

Punching Press



422

Bolster plate



423

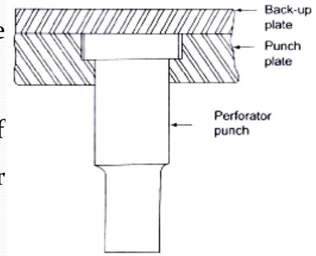
Bolster plate Contd....

- When many dies are to run in the same press at different times, the wear occurring on the press bed is high. The bolster plate is incorporated to take this wear.
- Relatively cheap and easy to replace.
- Attached to the press bed and the die shoe is then attached to it.

424

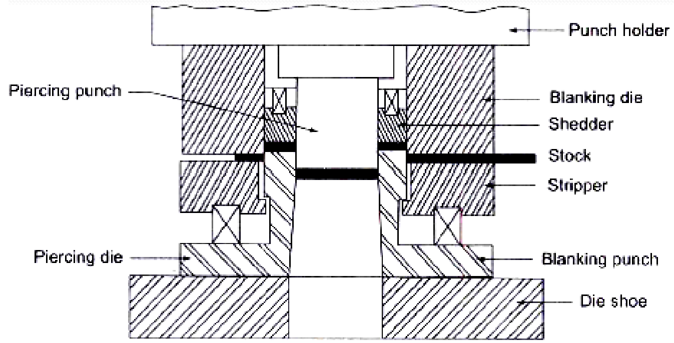
Punch plate

- Used to locate and hold the punch in position.
- This is a useful way of mounting, especially for small punches.



425

Stripper



426

Stripper Contd....

- The stripper removes the stock from the punch after a piercing or blanking operation.

$$P_s = KLt$$

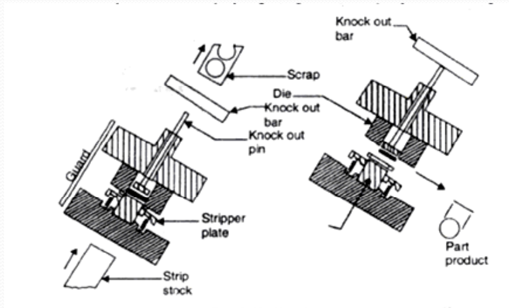
Where P_s = stripping force, kN
L = perimeter of cut, mm
t = stock thickness, mm

K = stripping constant,
= 0.0103 for low- carbon steels thinner than 1.5 mm with the cut at the edge or near a preceding cut
= 0.0145 for same materials but for other cuts
= 0.0207 for low- carbon steels above 1.5-mm thickness
= 0.0241 for harder materials

427

Knockout

- Knockout is a mechanism, usually connected to and operated by the press ram, for freeing a work piece from a die.



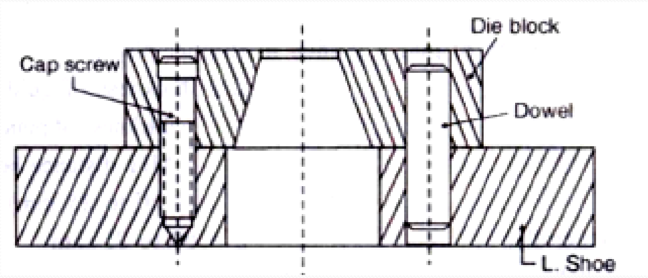
428

Pitman

- It is a connecting rod which is used to transmit motion from the main drive shaft to the press slide.

429

Dowel pin



430

GATE 2011

The shear strength of a sheet metal is 300 MPa. The blanking force required to produce a blank of 100 mm diameter from a 1.5 mm thick sheet is close to

(a) 45 kN
(b) 70 kN
(c) 141 kN
(d) 3500 kN

431

GATE-2016

In a sheet metal of 2 mm thickness a hole of 10 mm diameter needs to be punched. The yield strength in tension of the sheet material is 100 MPa and its ultimate shear strength is 80 MPa. The force required to punch the hole (in kN) is _______

432

GATE – 2009 (PI)

A disk of 200 mm diameter is blanked from a strip of an aluminum alloy of thickness 3.2 mm. The material shear strength to fracture is 150 MPa. The blanking force (in kN) is

(a) 291 (b) 301 (c) 311 (d) 321

433

GATE-2013 (PI)

Circular blanks of 10 mm diameter are punched from an aluminium sheet of 2 mm thickness. The shear strength of aluminium is 80 MPa. The minimum punching force required in kN is

(a) 2.57

(b) 3.29

(c) 5.03

(d) 6.33

434

ISRO-2009

The force required to punch a 25 mm hole in a mild steel plate 10 mm thick, when ultimate shear stress of the plate is 500 N/mm² will be nearly

(a) 78 kN (b) 393 kN (c) 98 kN (d) 158 kN

435

GATE-2007

The force requirement in a blanking operation of low carbon steel sheet is 5.0 kN. The thickness of the sheet is 't' and diameter of the blanked part is 'd'. For the same work material, if the diameter of the blanked part is increased to 1.5 d and thickness is reduced to 0.4 t, the new blanking force in kN is

(a) 3.0 (b) 4.5

(c) 5.0 (d) 8.0

436

GATE-2004

10 mm diameter holes are to be punched in a steel sheet of 3 mm thickness. Shear strength of the material is 400 N / mm² and penetration is 40%. Shear provided on the punch is 2 mm. The blanking force during the operation will be

(a) 22.6 kN (b) 37.7 kN

(c) 61.6 kN (d) 94.3 kN

437

GATE - 2012

Calculate the punch size in mm, for a circular blanking operation for which details are given below.

Size of the blank	25 mm
Thickness of the sheet	2 mm
Radial clearance between punch and die	0.06 mm
Die allowance	0.05 mm

(a) 24.83 (b) 24.89

(c) 25.01 (d) 25.17

438

GATE-2008(PI)

A blank of 50 mm diameter is to be sheared from a sheet of 2.5 mm thickness. The required radial clearance between the die and the punch is 6% of sheet thickness. The punch and die diameters (in mm) for this blanking operation, respectively, are

(a) 50.00 and 50.30 (b) 50.00 and 50.15

(c) 49.70 and 50.00 (d) 49.85 and 50.00

439

GATE-2002

In a blanking operation, the clearance is provided on

(a) The die

(b) Both the die and the punch equally

(c) The punch

(d) Brittle the punch nor the die

440

GATE-2001

The cutting force in punching and blanking operations mainly depends on

(a) The modulus of elasticity of metal

(b) The shear strength of metal

(c) The bulk modulus of metal

(d) The yield strength of metal

441

GATE-1996

A 50 mm diameter disc is to be punched out from a carbon steel sheet 1.0 mm thick. The diameter of the punch should be

(a) 49.925 mm (b) 50.00 mm

(c) 50.075 mm (d) none of the above

442

IES – 1994

In sheet metal blanking, shear is provided on punches and dies so that

(a) Press load is reduced

(b) Good cut edge is obtained.

(c) Warping of sheet is minimized

(d) Cut blanks are straight.

443

IES – 2002

Consider the following statements related to piercing and blanking:

1. Shear on the punch reduces the maximum cutting force
2. Shear increases the capacity of the press needed
3. Shear increases the life of the punch
4. The total energy needed to make the cut remains unaltered due to provision of shear

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 4

(c) 2 and 3 (d) 3 and 4

444

IAS – 1995

In blanking operation the clearance provided is

(a) 50% on punch and 50% on die

(b) On die

(c) On punch

(d) On die or punch depending upon designer's choice

445

IES – 2006

In which one of the following is a flywheel generally employed?

(a) Lathe (b) Electric motor

(c) Punching machine (d) Gearbox

446

IES – 2004

Which one of the following statements is correct?

If the size of a flywheel in a punching machine is increased

(a) Then the fluctuation of speed and fluctuation of energy will both decrease

(b) Then the fluctuation of speed will decrease and the fluctuation of energy will increase

(c) Then the fluctuation of speed will increase and the fluctuation of energy will decrease

(d) Then the fluctuation of speed and fluctuation of energy both will increase

447

IES – 1997

For 50% penetration of work material, a punch with single shear equal to thickness will

(a) Reduce the punch load to half the value

(b) Increase the punch load by half the value

(c) Maintain the same punch load

(d) Reduce the punch load to quarter load

448

IAS – 2000

A blank of 30 mm diameter is to be produced out of 10 mm thick sheet on a simple die. If 6% clearance is recommended, then the nominal diameters of die and punch are respectively

(a) 30.6 mm and 29.4 mm

(b) 30.6 mm and 30 mm

(c) 30 mm and 29.4 mm

(d) 30 mm and 28.8 mm

449

GATE – 2007 (PI)

Circular blanks of 35 mm diameter are punched from a steel sheet of 2 mm thickness. If the clearance per side between the punch and die is to be kept as 40 microns, the sizes of punch and die should respectively be

(a) $35^{+0.00}$ and $35^{+0.040}$ (b) $35^{-0.040}$ and $35^{-0.080}$

(c) $35^{-0.080}$ and $35^{+0.00}$ (d) $35^{+0.040}$ and $35^{-0.080}$

450

IAS – 1994

In a blanking operation to produce steel washer, the maximum punch load used in 2 x 10^5 N. The plate thickness is 4 mm and percentage penetration is 25. The work done during this shearing operation is

(a) 200J (b) 400J

(c) 600 J (d) 800 J

451

IAS – 2002

In deciding the clearance between punch and die in press work in shearing, the following rule is helpful:

(a) Punch size controls hole size die size controls blank size

(b) Punch size controls both hole size and blank size

(c) Die size controls both hole size and blank size

(d) Die size controls hole size, punch size controls blank size

452

IAS – 2007

For punching operation the clearance is provided on which one of the following?

(a) The punch

(b) The die

(c) 50% on the punch and 50% on the die

(d) 1/3rd on the punch and 2/3rd on the die

453

IAS – 1995

Assertion (A): A flywheel is attached to a punching press so as to reduce its speed fluctuations. Reason(R): The flywheel stores energy when its speed increase.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

454

IES – 2002, GATE(PI)-2003

Which one is *not* a method of reducing cutting forces to prevent the overloading of press?

(a) Providing shear on die

(b) Providing shear on punch

(c) Increasing die clearance

(d) Stepping punches

455

IAS – 2003

Match List I (Press-part) with List II (Function) and select the correct answer using the codes given below the lists:

List-I (Press-part)	**List-II (Function)**
(A) Punch plate	1. Assisting withdrawal of the punch
(B) Stripper	2. Advancing the work-piece through correct distance
(C) Stopper	3. Ejection of the work-piece from die cavity
(D) Knockout	4. Holding the small punch in the proper position

Codes:

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	2	1	4	3
(c)	4	1	2	3	(d)	2	3	4	1

456

IES – 2000

Best position of crank for blanking operation in a mechanical press is

(a) Top dead centre

(b) 20 degrees below top dead centre

(c) 20 degrees before bottom dead centre

(d) Bottom dead centre

457

IES – 1999

Assertion (A): In sheet metal blanking operation, clearance must be given to the die.

Reason (R): The blank should be of required dimensions.

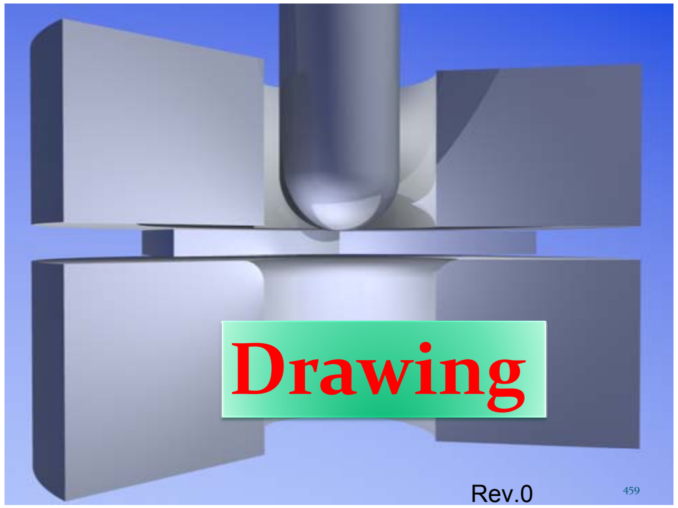
(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

458

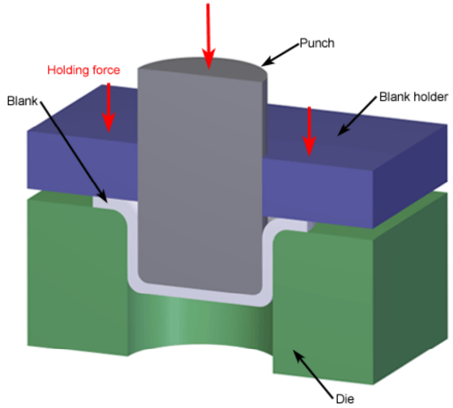


459

Drawing

- Drawing is a plastic deformation process in which a flat sheet or plate is formed into a three-dimensional part with a depth more than several times the thickness of the metal.
- As a punch descends into a mating die, the metal assumes the desired configuration.

460



461

Drawing

- Hot drawing is used for thick-walled parts of simple geometries, thinning takes place.
- Cold drawing uses relatively thin metal, changes the thickness very little or not at all, and produces parts in a wide variety of shapes.

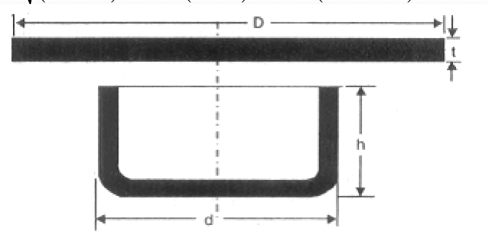
462

Blank Size

$$D = \sqrt{d^2 + 4dh} \quad \text{When d > 20r}$$

$$D = \sqrt{d^2 + 4dh} - 0.5r \quad \text{when } 15r \le d \le 20r$$

$$D = \sqrt{(d-2r)^2 + 4d(h-r) + 2\pi r(d-0.7r)} \quad \text{when } d < 10r$$



463

IES – 1994

For obtaining a cup of diameter 25 mm and height 15 mm by drawing, the size of the round blank should be approximately

(a) 42 mm (b) 44 mm

(c) 46 mm (d) 48 mm

464

GATE-2003

A shell of 100 mm diameter and 100 mm height with the corner radius of 0.4 mm is to be produced by cup drawing. The required blank diameter is

(a) 118 mm (b) 161 mm

(c) 224 mm (d) 312 mm

465

GATE-2017

A 10 mm deep cylindrical cup with diameter of 15 mm is drawn from a circular blank. Neglecting the variation in the sheet thickness, the diameter (up to 2 decimal points accuracy) of the blank is ______ mm.

466

ISRO-2011

The initial blank diameter required to form a cylindrical cup of outside diameter 'd' and total height 'h' having a corner radius 'r' is obtained using the formula

(a) $D_o = \sqrt{d^2 + 4dh} - 0.5r$

(b) $D_o = d + 2h + 2r$

(c) $D_o = d^2 + 2h^2 + 2r$

(d) $D_o = \sqrt{d^2 + 4dh - 0.5r}$

467

- **Drawing Force**

$$F = \pi d t \sigma \left[\frac{D}{d} - C\right]$$

F = Drawing Force, N

t = Original Blank Thickness, mm

σ = Tensile Strength, MPa

d = Punch Diameter, mm

D = Starting Blank Diameter, mm

C = 0.7 a correction factor to account for friction

468

Example

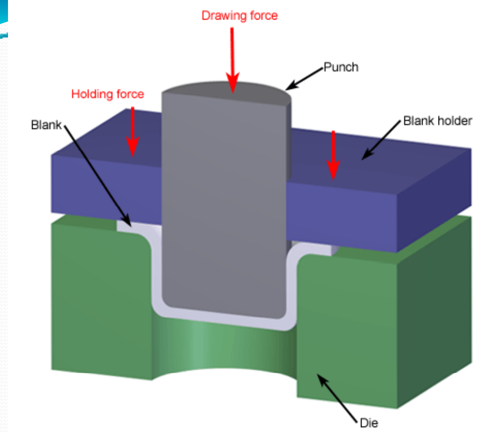
- A cup of 50 mm diameter and 20 mm height is to be produced by drawing from a 1.5 mm thick sheet metal. What is the maximum drawing force ? If ultimate tensile strength of metal is 650 MPa.

469

- **Blank Holding Force**
  Blank holding force required depends on the wrinkling tendency of the cup. The maximum limit is generally to be one-third of the drawing force.

- **Draw Clearance**
  Punch diameter = Die opening diameter – 2.5 t

470



471

IAS – 2013 Main

A cup, of 50 mm diameter and 100 mm height, is to be drawn from low carbon steel sheet. Neglecting the influence of thickness and corner radii:

(i) Calculate the blank diameter

(ii) Decide whether it can be drawn in a single draw, if maximum reduction permitted is 40%.

[10 marks]

472

IFS-2013

A symmetrical cup of circular cross section with diameter 40 mm and height 60 mm with a corner radius of 2 mm is to be obtained in C20 steel of 0.6 mm thickness. Calculate the blank size for the drawn cup. Will it be possible to draw the cup in single step?

[10 Marks]

473

Deep drawing

- Drawing when cup height is more than half the diameter is termed deep drawing.
- Easy with ductile materials.
- Due to the radial flow of material, the side walls increase in thickness as the height is increased.
- A cylindrical vessel with flat bottom can be deep drawn by double action deep drawing.
- Deep drawing - is a combination of drawing and stretching.

474

IES – 2008

A cylindrical vessel with flat bottom can be deep drawn by

(a) Shallow drawing

(b) Single action deep drawing

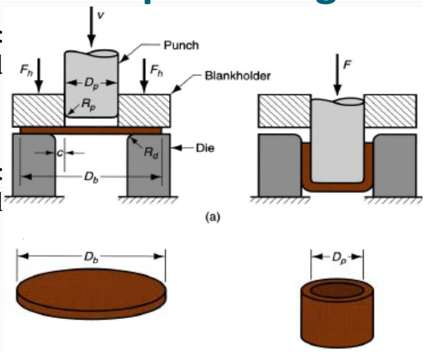
(c) Double action deep drawing

(d) Triple action deep drawing

475

Stresses on Deep Drawing

- In flange of blank: Bi-axial tension and compression
- In wall of the cup: simple uni-axial tension



476

Deep Drawability

- The ratio of the maximum blank diameter to the diameter of the cup drawn . *i.e. D/d.*
- There is a limiting drawing ratio (LDR), after which the punch will pierce a hole in the blank instead of drawing.
- This ratio depends upon material, amount of friction present, etc.
- Limiting drawing ratio (LDR) is 1.6 to 2.3

477

Limiting Drawing Ratio (LDR)

- The average reduction in deep drawing

$$\frac{d}{D} = 0.5$$

$$\text{Reduction} = \left(1 - \frac{d}{D}\right) \times 100\% = 50\%$$

Thumb rule:

First draw: Reduction = 50 %

Second draw: Reduction = 30 %

Third draw: Reduction = 25 %

Fourth draw: Reduction = 16 %

Fifth draw: Reduction = 13 %

IES – 1997

A cup of 10 cm height and 5 cm diameter is to be made from a sheet metal of 2 mm thickness. The number of deductions necessary will be

(a) One

(b) Two

(c) Three

(d) Four

IES – 1998

Assertion (A): The first draw in deep drawing operation can have up to 60% reduction, the second draw up to 40% reduction and, the third draw of about 30% only.

Reason (R): Due to strain hardening, the subsequent draws in a deep drawing operation have reduced percentages.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

IFS - 2009

What is deep drawing process for sheet metal forming? Explain the function of a blank holder. What is drawing ratio and how is the drawing ratio increased ?

[10 – marks]

IFS-2016

Estimate the limiting drawing ratio (LDR) that you would expect from a sheet metal when stretched by 23% in length, decreases thickness by 10%.

[8-Marks]

For IES Only

Die Design

- **Progressive dies**
- **Compound dies**
- **Combination dies**

For IES Only

Progressive dies

Perform two or more operations simultaneously in a single stroke of a punch press, so that a complete component is obtained for each stroke.

Compound dies

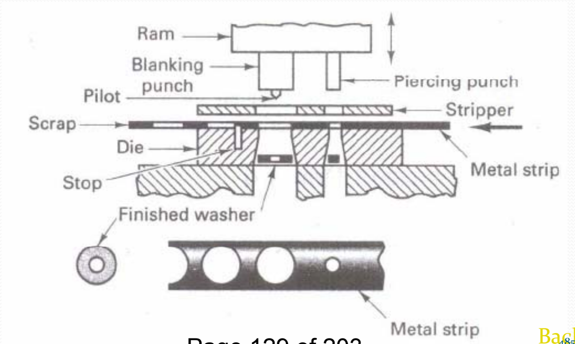
All the necessary operations are carried out at a single station, in a single stroke of the ram. To do more than one set of operations, a compound die consists of the necessary sets of punches and dies.

Combination dies

A combination die is same as that of a compound die with the main difference that here non-cutting operations such as bending and forming are also included as part of the operation.

For IES Only

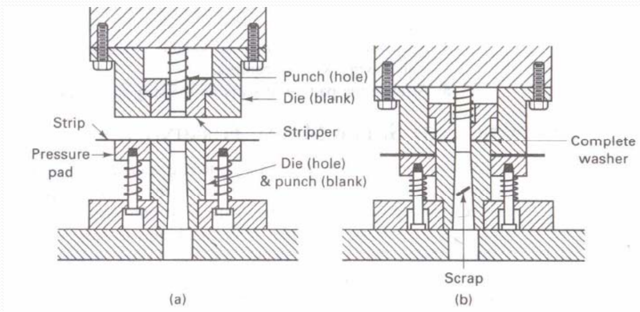
Progressive piercing and blanking die for making a simple washer.



Back

For IES Only

Method for making a simple washer in a compound piercing and blanking die. Part is blanked (a) and subsequently pierced (b) The blanking punch contains the die for piercing.



Back

IAS-1996

Compound die performs

(a) Two or more operations at one station in one stroke

(b) Two or more operations at different stations in one stroke

(c) high frequency sound wave

(d) High frequency eddy current

IFS-2013

- Differentiate among the simple, compound and progressive dies.

[6 – Marks]

Lubrication

- In drawing operation, proper lubrication is essential for
  1. To improve die life.
  2. To reduce drawing forces.
  3. To reduce temperature.
  4. To improve surface finish.

IAS – 2007

In drawing operation, proper lubrication is essential for which of the following reasons?

1. To improve die life
2. To reduce drawing forces
3. To reduce temperature
4. To improve surface finish

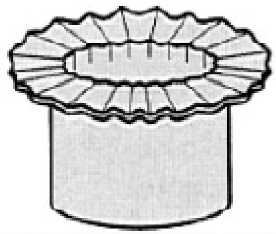
Select the correct answer using the code given below:

(a) 1 and 2 only (b) 1, 3 and 4 only

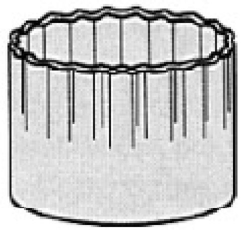
(c) 3 and 4 only (d) 1, 2, 3 and 4

Defects in Drawing - wrinkle

- An insufficient blank holder pressure causes wrinkles to develop on the flange, which may also extend to the wall of the cup.



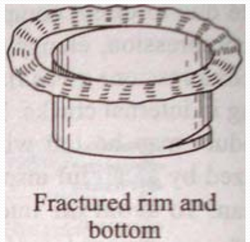
Flange Wrinkle

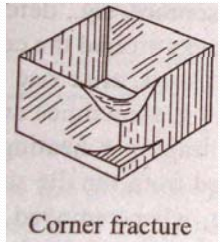


Wall Wrinkle

Defects in Drawing - Fracture

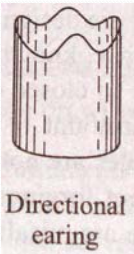
- Further, too much of a blank holder pressure and friction may cause a thinning of the walls and a fracture at the flange, bottom, and the corners (if any).





Defects in Drawing -earing

- While drawing a rolled stock, ears or lobes tend to occur because of the anisotropy induced by the rolling operation.



IES-1999

Consider the following statements:

Earing in a drawn cup can be due non-uniform

1. Speed of the press
2. Clearance between tools
3. Material properties
4. Blank holding

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4

(c) 1, 3 and 4 (d) 1, 2 and 4

Defects in Drawing – miss strike

- Due to the misplacement of the stock, unsymmetrical flanges may result. This defect is known as miss strike.

Defects in Drawing – Orange peel

- A surface roughening (defect) encountered in forming products from metal stock that has a coarse grain size.
- It is due to uneven flow or to the appearance of the overly large grains usually the result of annealing at too high a temperature.

496

Stretcher strains (like Luders Lines)

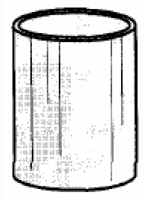
- Caused by plastic deformation due to inhomogeneous yielding.
- These lines can criss-cross the surface of the workpiece and may be visibly objectionable.
- Low carbon steel and aluminium shows more stretcher strains.

Stretcher Strains

497

Surface scratches

- Die or punch not having a smooth surface, insufficient lubrication



498

GATE-2008

In the deep drawing of cups, blanks show a tendency to wrinkle up around the periphery (flange).

The most likely cause and remedy of the phenomenon are, respectively,

(A) Buckling due to circumferential compression; Increase blank holder pressure

(B) High blank holder pressure and high friction; Reduce blank holder pressure and apply lubricant

(C) High temperature causing increase in circumferential length: Apply coolant to blank

(D) Buckling due to circumferential compression; decrease blank holder pressure

499

IAS – 1997

Which one of the following factor promotes the tendency for wrinking in the process of drawing?

(a) Increase in the ratio of thickness to blank diameter of work material

(b) Decrease in the ratio thickness to blank diameter of work material

(c) Decrease in the holding force on the blank

(d) Use of solid lubricants

500

GATE-1999

Identify the stress - state in the FLANCE portion of a PARTIALLYDRAWN CYLINDRICAL CUP when deep - drawing without a blank holder

(a) Tensile in all three directions

(b) No stress in the flange at all, because there is no blank-holder

(c) Tensile stress in one direction and compressive in the one other direction

(d) Compressive in two directions and tensile in the third direction

501

GATE-2006

Match the items in columns I and II.

	Column I		Column II
P.	Wrinkling	1.	Yield point elongation
Q.	Orange peel	2.	Anisotropy
R.	Stretcher strains	3.	Large grain size
S.	Earing	4.	Insufficient blank holding force
		5.	Fine grain size
		6.	Excessive blank holding force

(a) P – 6, Q – 3, R – 1, S – 2 (b) P – 4, Q – 5, R – 6, S – 1

(c) P – 2, Q – 5, R – 3, S – 4 (d) P – 4, Q – 3, R – 1, S – 2

502

IES – 1999

Consider the following statements: Earring in a drawn cup can be due to non-uniform

1. Speed of the press
2. Clearance between tools
3. Material properties
4. Blank holding

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4

(c) 1, 3 and 4 (d) 1, 2 and 4

503

IAS – 1994

Consider the following factors

1. Clearance between the punch and the die is too small.
2. The finish at the corners of the punch is poor.
3. The finish at the corners of the die is poor.
4. The punch and die alignment is not proper.

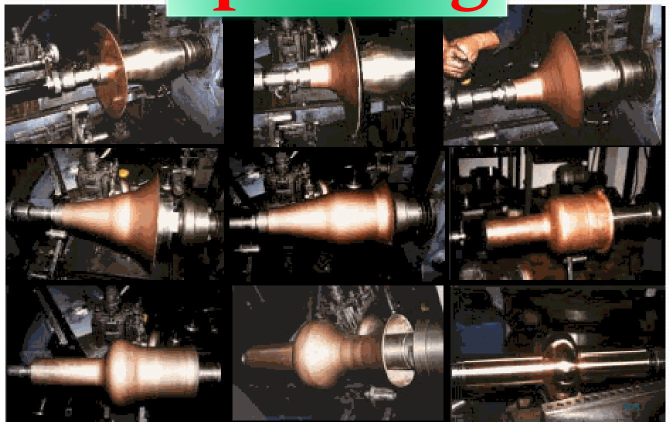
The factors responsible for the vertical lines parallel to the axis noticed on the outside of a drawn cylindrical cup would include.

(a) 2, 3 and 4 (b) 1 and 2

(c) 2 and 4 (d) 1, 3 and 4

504

Spinning



Spinning

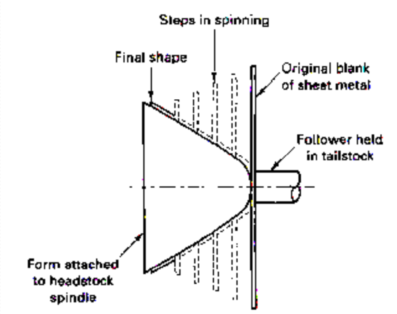
- Spinning is a cold-forming operation in which a rotating disk of sheet metal is shaped over a male form, or mandrel.
- Localized pressure is applied through a simple round-ended wooden or metal tool or small roller, which traverses the entire surface of the part

506

Spinning

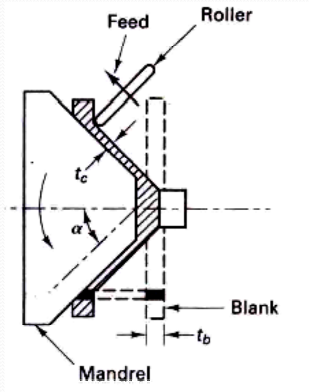
1. A mandrel (or die for internal pieces) is placed on a rotating axis (like a turning center).
2. A blank or tube is held to the face of the mandrel.
3. A roller is pushed against the material near the center of rotation, and slowly moved outwards, pushing the blank against the mandrel.
4. The part conforms to the shape of the mandrel (with some springback).
5. The process is stopped, and the part is removed and trimmed.

507



508

$$t_c = t_b \sin\alpha$$



509

GATE-1992

The thickness of the blank needed to produce, by power spinning a missile cone of thickness 1.5 mm and half cone angle 30°, is

(a) 3.0 mm (b) 2.5 mm

(c) 2.0 mm (d) 1.5 mm

510

IES – 1994

The mode of deformation of the metal during spinning is

(a) Bending

(b) Stretching

(c) Rolling and stretching

(d) Bending and stretching.

IFS-2011

Compare metal spinning with press work.

[2-marks]

For IES Only

High Energy Rate Forming(HERF)

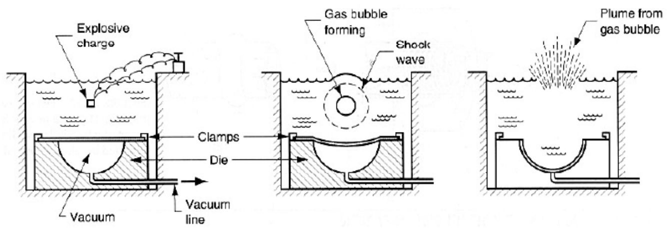
HERF

- High Energy Rate Forming, also known as HERF or explosive forming can be utilised to form a wide variety of metals, from aluminum to high strength alloys.
- Applied a large amount of energy in a very sort time interval.
- HERF makes it possible to form large work pieces and difficult-to-form metals with less-expensive equipment and tooling required.
- No springback

HERF

- Underwater explosions.
- Underwater spark discharge (electro-hydraulic).
- Pneumatic-mechanical means
- Internal combustion of gaseous mixtures.
- Electro-magnetic (the use of rapidly formed magnetic fields).

Underwater Explosions



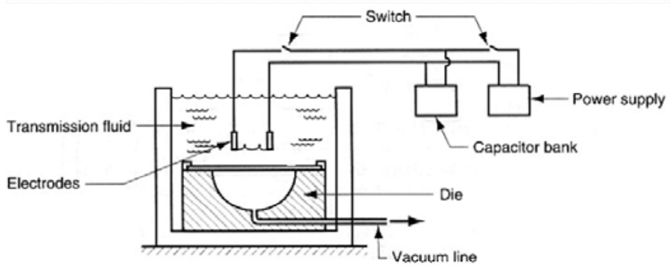
(1) (2) (3)
Explosive forming: (1) set-up, (2) explosive is detonated, and (3) shock wave forms part

Underwater explosions

- A shock wave in the fluid medium (normally water) is generated by detonating an explosive charge.
- TNT and dynamite for higher energy and gun powder for lower energy is used.
- Used for parts of thick materials.
- Employed in Aerospace, aircraft industries and automobile related components.

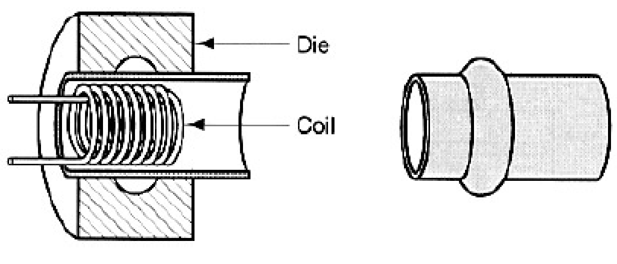
Electro-hydraulic Forming

- An operation using electric discharge in the form of sparks to generate a shock wave in a fluid is called electrohydrulic forming.
- A capacitor bank is charged through the charging circuit, subsequently, a switch is closed, resulting in a spark within the electrode gap to discharge the capacitors.
- Energy level and peak pressure is lower than underwater explosions but easier and safer.
- Used for bulging operations in small parts.



Electromagnetic or Magnetic Pulse Forming

- Based on the principle that the electromagnetic field of an induced current always opposes the electromagnetic field of the inducing current.
- A large capacitor bank is discharged, producing a current surge through a coiled conductor.
- If the coil has been placed within a conductive cylinder, around a cylinder, or adjacent the flat sheet of metal, the discharge induces a secondary current in the workpiece, causing it to be repelled from the coil and conformed to a die or mating workpiece.



(1) (2)
Electromagnetic forming: (1) set-up in which coil is inserted into tubular workpiece surrounded by die, (2) formed part

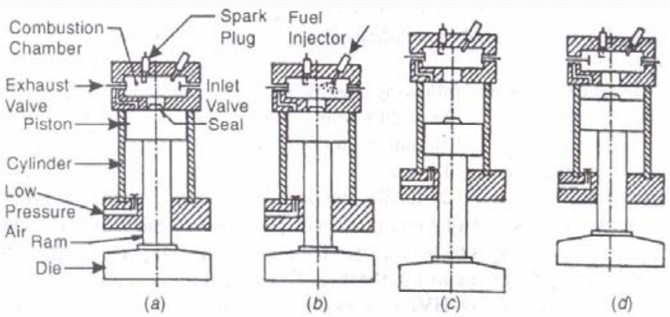
Electromagnetic or Magnetic Pulse Forming

- The process is very rapid and is used primarily to expand or contract tubing, or to permanently assemble component parts.
- This process is most effective for relatively thin materials (0.25 to 1.25 mm thick).
- The workpiece must be electrically conductive but need not be magnetic.
- Short life of the coil is the major problem.

Petro - Forging or Petro - Forge Forming

- In this process, the stored chemical energy of a hydrocarbon, like petrol or diesel is utilized to move the dies at very high velocity. The principle of working of a Petro-forge hammer is just similar to I.C. engine.
- It is a piston-cylinder arrangement and a piston drives a ram (piston rod) and a die.
- After air-fuel mixture is ignited in the combustion chamber pressure increases by 5 to 7 times which breaks the seal and the high pressure gases act on the top face of the piston.
- The piston, ram and die are accelerated at a very rapid rate and strike upto 250 m/s.

523



524

IES 2016

Consider the following in case of high energy forming processes:

1. **The evacuation between die and blank in explosive forming forming is done by a vacuum pump.**
2. **The pressure waves produced in water in explosive forming deform the blank to the die shape.**
3. **The electrohydraulic forming makes use of discharge of large amount of electrical energy used in a capacitor bank.**
4. **In Petroforge, the piston is moved by combustion of fuel moving at the rate of 150 – 200 m/s.**

Which of the above are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only
(c) 3 and 4 only (d) 1, 2 and 4 only

525

IES 2011

High energy rate forming process used for forming components from thin metal sheets or deform thin tubes is:

(a) Petro-forming

(b) Magnetic pulse forming

(c) Explosive forming

(d) electro-hydraulic forming

526

JWM 2010

Assertion (A) : In magnetic pulse-forming method, magnetic field produced by eddy currents is used to create force between coil and workpiece.

Reason (R) : It is necessary for the workpiece material to have magnetic properties.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

527

IES 2010

Assertion (A) : In the high energy rate forming method, the explosive forming has proved to be an excellent method of utilizing energy at high rate and utilizes both the high explosives and low explosives.

Reason (R): The gas pressure and rate of detonation can be controlled for both types of explosives.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

528

IES – 2007

Which one of the following metal forming processes is not a high energy rate forming process?

(a) Electro-mechanical forming

(b) Roll-forming

(c) Explosive forming

(d) Electro-hydraulic forming

529

IES – 2009

Which one of the following is a high energy rate forming process?

(a) Roll forming

(b) Electro-hydraulic forming

(c) Rotary forging

(d) Forward extrusion

530

IES – 2005

Magnetic forming is an example of:

(a) Cold forming (b) Hot forming

(c) High energy rate forming (d) Roll forming

531

IES-2013 Conventional

- Name at least four methods by which high energy release rates are obtained.
- Why might less springback be observed in HERF?

[5 marks]

532

Stretch Forming

- Produce large sheet metal parts in low or limited quantities.
- A sheet of metal is gripped by two or more sets of jaws that stretch it and wrap it around a single form block.
- Because most of the deformation is induced by the tensile stretching, the forces on the form block are far less than those normally encountered in bending or forming.
- There is very little springback, and the workpiece conforms very closely to the shape of the tool.
- Because the forces are so low, the form blocks can often be made of wood, low-melting-point metal, or even plastic.

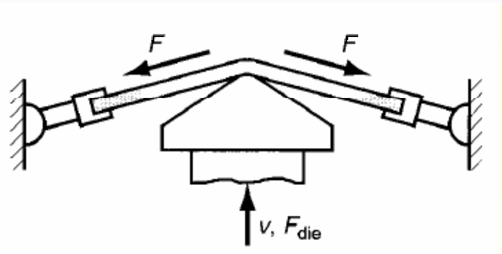
533

Stretch Forming Contd......

- Popular in the aircraft industry and is frequently used to form aluminum and stainless steel
- Low-carbon steel can be stretch formed to produce large panels for the automotive and truck industry.

534

Stretch Forming Contd......



535

Stretch Forming Contd......

For bi-axial stretching of sheets

$$\varepsilon_1 = \ln\left(\frac{l_{i1}}{l_{o1}}\right) \quad ; \quad \varepsilon_2 = \ln\left(\frac{l_{i2}}{l_{o2}}\right)$$

$$\text{Final thickness} = \frac{\text{Initial thickness(t)}}{e^{\varepsilon_1} \times e^{\varepsilon_2}}$$

536

GATE-2000

A 1.5 mm thick sheet is subject to unequal biaxial stretching and the true strains in the directions of stretching are 0.05 and 0.09. The final thickness of the sheet in mm is

(a) 1.414 (b) 1.304

(c) 1.362 (d) 289

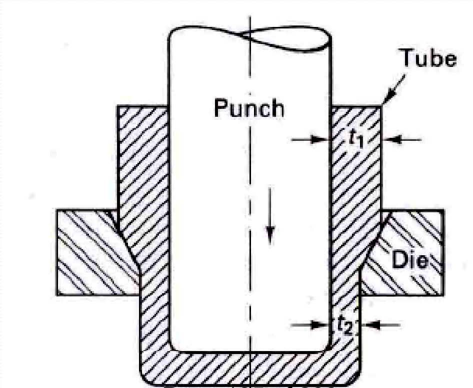
537

Ironing

- The process of thinning the walls of a drawn cylinder by passing it between a punch and die whose separation is less than the original wall thickness.
- The walls are thinned and lengthened, while the thickness of the base remains unchanged.
- Examples of ironed products include brass cartridge cases and the thin-walled beverage can.

538

Ironing Contd....



539

For IES Only

Ironing Force

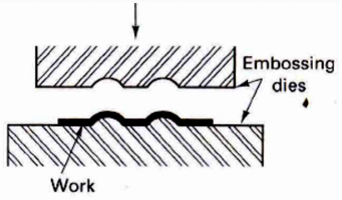
- Neglecting the friction and shape of the die, the ironing force can be estimated using the following equation.

$$F = \pi d_t t_t \sigma_{av} \ln\left(\frac{t_o}{t_t}\right)$$

540

Embossing

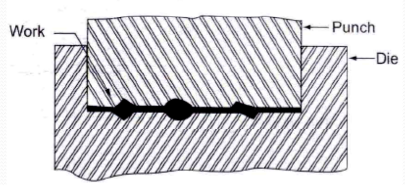
- It is a very shallow drawing operation where the depth of the draw is limited to one to three times the thickness of the metal, and the material thickness remains largely unchanged.



541

Coining

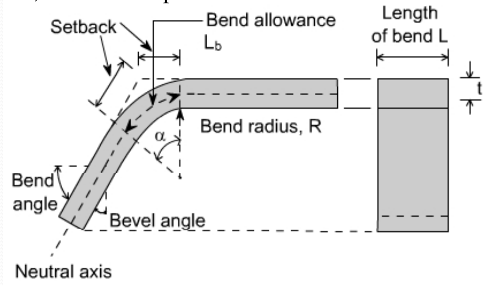
- Coining is essentially a cold-forging operation except for the fact that the flow of the metal occurs only at the top layers and not the entire volume.
- Coining is used for making coins, medals and similar articles.



542

Bending

- After basic shearing operation, we can bend a part to give it some shape.
- Bending parts depends upon material properties at the location of the bend.
- At bend, bi-axial compression and bi-axial tension is there.



543

Bending

Bend allowance,

$$L_b = \alpha(R + kt)$$

where

R = bend radius

k = constant (stretch factor)

$$For\ R > 2t \qquad k = 0.5$$

$$For\ R < 2t \qquad k = 0.33$$

t = thickness of material

α = bend angle (in radian)

544

Bending

- The strain on the outermost fibers of the bend is

$$\varepsilon = \frac{1}{\frac{2R}{t} + 1}$$

545

For IES Only

Bending Force

$$F = \frac{Kl\sigma_{ut}t^2}{w}$$

Where l=Bend length = width of the stock, mm

σ_{ut} = Ultimate tensile strength, MPa (N/mm^2)

t = blank thickness, mm

w = width of die-opening, mm

K = die-opening factor, (can be used followin table)

Condition	V-Bending	U-Bending	Edge-Bending
W < 16t	1.33	2.67	0.67
W > = 16t	1.20	2.40	0.6

For U or channel bending force required is double than V – bending

For edge bending it will be about one-half that for V - bending

546

IES-1998

The bending force required for V-bending, U-bending and Edge bending will be in the ratio of

(a) 1 : 2 : 0.5 (b) 2: 1 : 0.5

(c) 1: 2 : 1 (d) 1: 1 : 1

547

Example

- Calculate the bending force for a 45° bend in aluminium blank. Blank thickness, 1.6 mm, bend length = 1200 mm, Die opening = 8t, UTS = 455 MPa, Die opening factor = 1.33

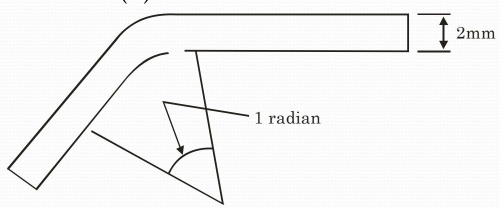
548

GATE-2005

A 2 mm thick metal sheet is to be bent at an angle of one radian with a bend radius of 100 mm. If the stretch factor is 0.5, the bend allowance is

(a) 99 mm (b) 100 mm

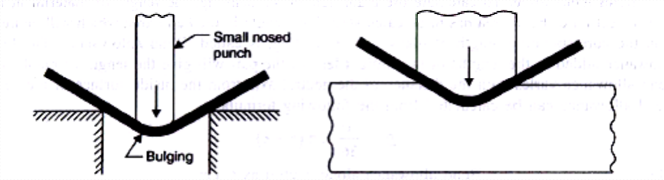
(c) 101 mm (d) 102 mm

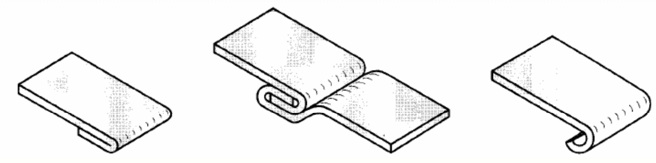


549

Spanking

- During bending, the area of the sheet under the punch has a tendency to flow and form a bulge on the outer surface.
- The lower die should be provided with mating surfaces, so that when the punch and die are completely closed on the blank, any bulging developed earlier will be completely presses or “spanked” out.





Hemming Seaming Curling

GATE-2007

Match the correct combination for following metal working processes.

Processes		**Associated state of stress**
P. Blanking	1.	Tension
Q. Stretch Forming	2.	Compression
R. Coining	3.	Shear
S. Deep Drawing	4.	Tension and Compression
	5.	Tension and Shear

Codes:	**P**	**Q**	**R**	**S**		**P**	**Q**	**R**	**S**
(a)	2	1	3	4	(b)	3	4	1	5
(c)	5	4	3	1	(d)	3	1	2	4

GATE -2012 Same Q in GATE-2012 (PI)

Match the following metal forming processes with their associated stresses in the workpiece.

Metal forming process	Type of stress
1. Coining	P. Tensile
2. Wire Drawing	Q. Shear
3. Blanking	R. Tensile and compressive
4. Deep Drawing	S. Compressive

(a) 1-S, 2-P, 3-Q, 4-R (b) 1-S, 2-P, 3-R, 4-Q
(c) 1-P, 2-Q, 3-S, 4-R (d) 1-P, 2-R, 3-Q, 4-S

GATE-2004

Match the following

Product		**Process**
P. Moulded luggage	1.	Injection moulding
Q. Packaging containers for liquid	2.	Hot rolling
R. Long structural shapes	3.	Impact extrusion
S. Collapsible tubes	4.	Transfer moulding
	5.	Blow moulding
	6.	Coining

(a) P-1 Q-4 R-6 S-3 (b) P-4 Q-5 R-2 S-3
(c) P-1 Q-5 R-3 S-2 (d) P-5 Q-1 R-2 S-2

IAS – 1999

Match List I (Process) with List II (Production of parts) and select the correct answer using the codes given below the lists:

List-I		**List-II**
A. Rolling	1.	Discrete parts
B. Forging	2.	Rod and Wire
C. Extrusion	3.	Wide variety of shapes with thin walls
D. Drawing	4.	Flat plates and sheets
	5.	Solid and hollow parts

Codes:	**A**	**B**	**C**	**D**		**A**	**B**	**C**	**D**
(a)	2	5	3	4	(b)	1	2	5	4
(c)	4	1	3	2	(d)	4	1	5	2

IAS – 1997

Match List-I (metal forming process) with List-II (Associated feature) and select the correct answer using the codes given below the Lists:

List-I		**List- II**
A. Blanking	1.	Shear angle
B. Flow forming	2.	Coiled stock
C. Roll forming	3.	Mandrel
D. Embossing	4.	Closed matching dies

Codes:	**A**	**B**	**C**	**D**		**A**	**B**	**C**	**D**
(a)	1	3	4	2	(b)	3	1	4	2
(c)	1	3	2	4	(d)	3	1	2	4

IES 2010

Consider the following statements:

The material properties which principally determine how well a metal may be drawn are

1. Ratio of yield stress to ultimate stress.
2. Rate of increase of yield stress relative to progressive amounts of cold work.
3. Rate of work hardening.

Which of the above statements is/are correct?

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 only (d) 1, 2 and 3

559

Powder Metallurgy

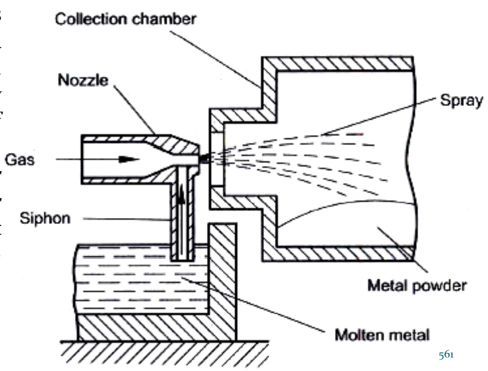
- Powder metallurgy is the name given to the process by which fine powdered materials are blended, pressed into a desired shape (compacted), and then heated (sintered) in a controlled atmosphere to bond the contacting surfaces of the particles and establish the desired properties.

560

Manufacturing of Powder

Atomization using a gas stream

Molten metal is forced through a small orifice and is disintegrated by a jet of compressed air, inert gas or water jet,. It is used for low melting point materials, brass, bronze, Zn, Tn, Al, Pb etc.



561

IAS – 2003

Assertion (A): Atomization method for production of metal powders consists of mechanical disintegration of molten stream into fine particles.

Reason (R): Atomization method is an excellent means of making powders from high temperature metals.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

562

IAS – 2007

Assertion (A): Mechanical disintegration of a molten metal stream into fine particles by means of a jet of compressed air is known as atomization.

Reason (R): In atomization process inert-gas or water cannot be used as a substitute for compressed air.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

563

IES-2016

Statement (I) : Metal powders can be produced by atomization process.

Statement (II) : In case of metals with low melting point, the size of particles cannot be controlled and the shape of the particles remains regular in atomization.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true

564

IES – 1999

Assertion (A): In atomization process of manufacture of metal powder, the molten metal is forced through a small orifice and broken up by a stream of compressed air.

Reason (R): The metallic powder obtained by atomization process is quite resistant to oxidation.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

565

GATE-2017(PI)

In powder metallurgy, the process 'atomization' refers to a method of

(a) Producing powders

(b) compaction of powders

(c) sintering of powder compacts

(d) blending of metal powders

566

Manufacturing of Powder

Reduction

- Metal oxides are turned to pure metal powder when exposed to below melting point gases results in a product of cake of sponge metal.
- The irregular sponge-like particles are soft, readily compressible, and give compacts of good pre-sinter ("green") strength
- Used for iron, Cu, tungsten, molybdenum, Ni and Cobalt.

567

GATE -2011 (PI)

Which of the following powder production methods produces spongy and porous particles?

(a) Atomization

(b) Reduction of metal oxides

(c) Electrolytic deposition

(d) Pulverization

568

Manufacturing of Powder

Grinding

This metallic powder is nothing but the unburnt tiny chips formed during the process of grinding.

569

Only for IES

Manufacturing of Powder

Comminution

- Granular material, which may be coarsely atomized powder, is fed in a stream of gas under pressure through a venturi and is cooled and thereby embrittled by the adiabatic expansion of the gas before impinging on a target on which the granules shatters
- Process is used for production of very fine powders such as are required for injection moulding . Brittle materials such as inter-metallic compounds, ferro-alloys - ferro-chromium, ferro-silicon are produces

570

IES-2013 Conventional

Explain the terms comminution and reduction used in powder metallurgy.

[2 marks]

571

Manufacturing of Powder

Electrolytic Deposition

- Used for iron, copper, silver
- Process is similar to electroplating.
- For making copper powder, copper plates are placed as anode in the tank of electrolyte, whereas the aluminium plates are placed in the electrolyte to act as cathode. When DC current is passed, the copper gets deposited on cathode. The cathode plated are taken out and powder is scrapped off. The powder is washed, dried and pulverized to the desired grain size.
- The cost of manufacturing is high.

572

IES - 2012

In electrolysis

(a) For making copper powder, copper plate is made cathode in electrolyte tank

(b) For making aluminum powder, aluminum plate is made anode

(c) High amperage produces powdery deposit of cathode metal on anode

(d) Atomization process is more suitable for low melting point metals

573

Manufacturing of Powder

Granulations - as metals are cooled they are stirred rapidly

Machining - coarse powders such as magnesium

Milling - crushers and rollers to break down metals. Used for brittle materials.

Shooting - drops of molten metal are dropped in water, used for low melting point materials.

Condensation – Metals are boiled to produce metal vapours and then condensed to obtain metal powders. Used for Zn, Mg, Cd.

574

GATE-2014 (PI)

Which one of the following methods is NOT used for producing metal powders?

(a) Atomization

(b) Compaction

(c) Machining and grinding

(d) Electrolysis

575

IAS – 2000

Consider the following processes:

1. Mechanical pulverization
2. Atomization
3. Chemical reduction
4. Sintering

Which of these processes are used for powder preparation in powder metallurgy?

(a) 2, 3 and 4 (b) 1, 2 and 3

(c) 1, 3 and 4 (d) 1, 2 and 4

576

IES 2010

Metallic powders can be produced by

(a) Atomization

(b) Pulverization

(c) Electro-deposition process

(d) All of the above

577

GATE-2018 (PI)

Which one of the following processes is NOT used for producing powders?

(a) Atomization

(b) Ball milling

(c) Sintering

(d) Electrolysis

578

Characteristics of metal powder:

- **Fineness:** refers to particle size of powder, can be determined either by pouring the powder through a sieve or by microscopic testing. A standard sieves with mesh size varies between (100) and (325) are used to determine particle size and particle size distribution of powder in a certain range.
- **Particle size distribution:** refers to amount of each particle size in the powder and have a great effect in determining flowability, apparent density and final porosity of product.

579

Conventional Questions

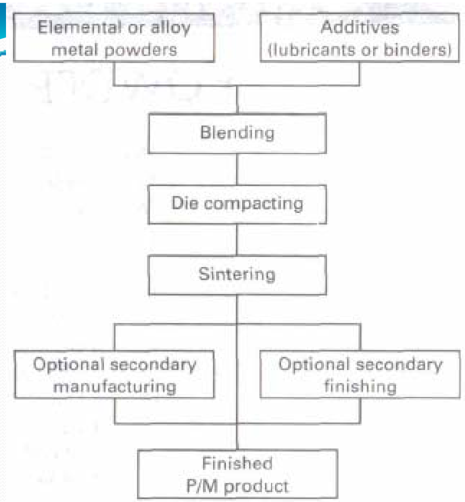
- **Discuss the terms fineness and particle size distribution in powder metallurgy. [IES-2010, 2 Marks]**

Ans.

Fineness: Is the diameter of spherical shaped particle and mean diameter of non-spherical shaped particle.

Particle size distribution: Geometric standard deviation (a measure for the bredth or width of a distribution), is the ratio of particle size diameters taken at 84.1 and 50% of the cumulative undersized weight plot, respectively and mean mass diameter define the particle size distribution.

580



581

IES – 1999

The correct sequence of the given processes in manufacturing by powder metallurgy is

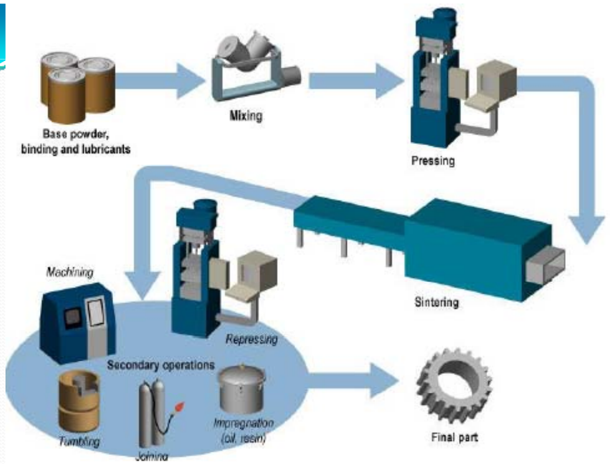
(a) Blending, compacting, sintering and sizing

(b) Blending, compacting, sizing and sintering

(c) Compacting, sizing, blending and sintering

(d) Compacting, blending, sizing and sintering

582



Steps of powder metallurgy

583

Blending

- Blending or mixing operations can be done either dry or wet.
- Lubricants such as graphite or stearic acid improve the flow characteristics and compressibility at the expense of reduced strength.
- Binders produce the reverse effect of lubricants. Thermoplastics or a water-soluble methylcellulose binder is used.
- Most lubricants or binders are not wanted in the final product and are removed (volatilized or burned off)

584

IES-2013 Conventional

Why lubricants are used to mix the metal powders?

[2 marks]

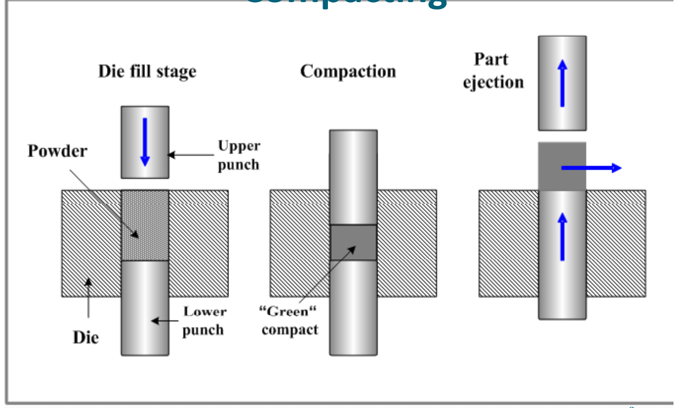
585

Compacting

- Powder is pressed into a "green compact"
- 40 to 1650 MPa pressure (Depends on materials, product complexity)
- Still very porous, ~70% density
- May be done cold or warm (higher density)

586

Compacting



587

Sintering

- Controlled atmosphere: no oxygen
- Heat to 0.75*T melt
- Particles bind together, diffusion, recrystalization and grain growth takes place.
- Part shrinks in size
- Density increases, up to 95%
- Strength increases, Brittleness reduces, Porosity decreases. Toughness increases.

588

GATE-2016 (PI)

In powder metallurgy, sintering of the component

(a) increases density and reduces ductility

(b) increases porosity and reduces density

(c) increases density and reduces porosity

(d) increases porosity and reduces brittleness.

589

GATE -2010 (PI)

In powder metallurgy, sintering of a component

(a) Improves strength and reduces hardness

(b) Reduces brittleness and improves strength

(c) Improves hardness and reduces toughness

(d) Reduces porosity and increases brittleness

590

IES – 2002

The rate of production of a powder metallurgy part depends on

(a) Flow rate of powder

(b) Green strength of compact

(c) Apparent density of compact

(d) Compressibility of powder

591

IES – 2007 Conventional

- **Metal powders are compacted by many methods, but sintering is required to achieve which property? What is hot iso-static pressing?**

[2 Marks]

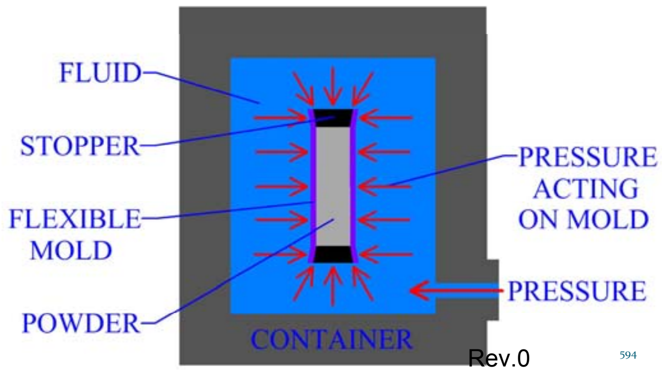
592

Cold Isostatic Pressing (CIP)

- The powder is contained in a flexible mould made of rubber or some other elastomer material
- The flexible mould is then pressurized by means of high-pressure water or oil. (same pressure in all directions)
- No lubricant is needed
- High and uniform density can be achieved

593

Cold Isostatic Pressing



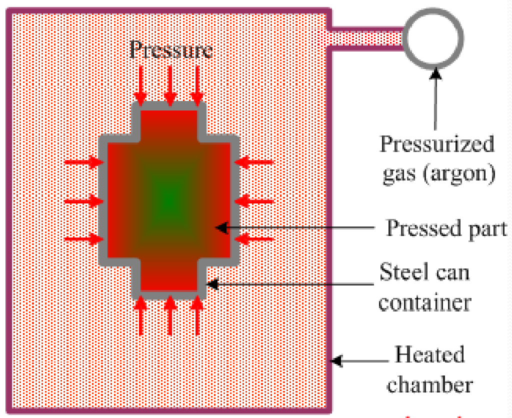
594

Hot Isostatic Pressing (HIP)

- Is carried out at high temperature and pressure using a gas such as argon.
- The flexible mould is made of sheet metal. (Due to high temperature)
- Compaction and sintering are completed simultaneously.
- Used in the production of billets of super-alloys, high-speed steels, titanium, ceramics, etc, where the integrity of the materials is a prime consideration

595

Hot isostatic pressing



596

IAS – 1997

Assertion (A): Close dimensional tolerances are NOT possible with isostatic pressing of metal powder in powder metallurgy technique.
Reason (R): In the process of isostatic pressing, the pressure is equal in all directions which permits uniform density of the metal powder.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

597

IES – 2011 Conventional

- **What is isostatic pressing of metal powders ?**
- **What are its advantage ?**

[2 Marks]

598

For IES Only

Spray Deposition

- Spray deposition is a shape-generation process.
- Basic components of a spray deposition process
  (a) Atomiser
  (b) Spray chamber with inert atmosphere
  (c) Mould for producing preforms.
- After the metal is atomised, it is deposited into a cooler preformed mould.
- Achieve density above 99%, fine grain structure, mechanical properties same as wrought product

599

For IES Only

Metal Injection Moulding

- Fine metal powders are blended with an organic binder such as a polymer or a wax-based binder.
- The powder-polymer mixture is then injected into split dies, preheated to remove the binder and, finally, sintered.
- Volumetric shrinkage during sintering is very high.
- Complex shapes that are impossible with conventional compaction.
- Good dimensional accuracy.
- High production rate.
- Good mechanical properties.

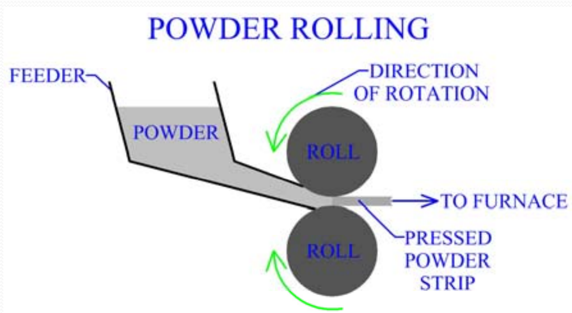
600

For IES Only

Roll Compaction

- Powders are compacted by passing between two rolls rotating in opposite direction.
- The powders are put in a container and are forced by a ram between two rotating rolls, and is compacted into a continuous strip at speeds of up to 0.5 m/s.
- Sheet metal for electrical and electronic components and for coins can be made by this process.
- The rolling processes can be carried out at room or at elevated temperature.

601



602

For IES Only

Explosive Compaction

- High Energy Rate Forming (HERF) or Explosive Forming of the metal powders at rather higher velocities 3500 m/s than that of the usual speed of compaction during the ordinary die compacting.
- Higher green densities
- Higher sintered strength
- More uniform density distribution

603

Liquid Phase Sintering

- During sintering a liquid phase, from the lower MP component, may exist
- Alloying may take place at the particle-particle interface
- Molten component may surround the particle that has not melted
- High compact density can be quickly attained
- Important variables:
  - Nature of alloy, molten component/particle wetting, capillary action of the liquid

604

ISRO -2013

Following is a process used to form powder metal to shape

(a) Sintering

(b) Explosive Compacting

(c) Isostatic Molding

(d) All of these

605

Features of PM products

- For high tolerance parts, a sintering part is put back into a die and repressed. In general this makes the part more accurate with a better surface finish.
- A part has many voids that can be impregnated. One method is to use an oil bath. Another method uses vacuum first, then impregnation.
- A part surface can be infiltrated with a low melting point metal to increase density, strength, hardness, ductility and impact resistance.
- Plating, heat treating and machining operations can also be used.

606

Production of magnets

- 50:50 Fe-Al alloys is used for magnetic parts
- Al-Ni-Fe is used for permanent magnets
- Sintering is done in a wire coil to align the magnetic poles of the material
- H_2 is used to rapidly cool the part (to maintain magnetic alignment)
- Total shrinkage is approximately 3-7% (for accurate parts an extra sintering step may be added before magnetic alignment)
- The sintering temperature is 600°C in H_2

607

Advantages

- Good tolerances and surface finish
- Highly complex shapes made quickly
- Can produce porous parts and hard to manufacture materials (e.g. cemented oxides)
- Pores in the metal can be filled with other materials/metals
- Surfaces can have high wear resistance
- Porosity can be controlled
- Low waste
- Automation is easy

608

Advantages Contd….

- Physical properties can be controlled
- Variation from part to part is low
- Hard to machine metals can be used easily
- No molten metals
- No need for many/any finishing operations
- Permits high volume production of complex shapes
- Allows non-traditional alloy combinations
- Good control of final density

609

GATE – 2009 (PI)

Which of the following process is used to manufacture products with controlled porosity?

(a) Casting

(b) welding

(c) formation

(d) Powder metallurgy

610

IES – 2007

What are the advantages of powder metallurgy?

1. Extreme purity product
2. Low labour cost
3. Low equipment cost.

Select the correct answer using the code given below

(a) 1, 2 and 3 (b) 1 and 2 only

(c) 2 and 3 only (d) 1 and 3 only

611

Disadvantages

- Metal powders deteriorate quickly when stored improperly
- Fixed and setup costs are high
- Part size is limited by the press, and compression of the powder used.
- Sharp corners and varying thickness can be hard to produce
- Non-moldable features are impossible to produce.

612

IES - 2012

Statement (I): Parts made by powder metallurgy do not have as good physical properties as parts casted.

Statement (II): Particle shape in powder metallurgy influences the flow characteristic of the powder.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

613

IES – 2006

Which of the following are the limitations of powder metallurgy?

1. High tooling and equipment costs.
2. Wastage of material.
3. It cannot be automated.
4. Expensive metallic powders.

Select the correct answer using the codes given below:

(a) Only 1 and 2 (b) Only 3 and 4
(c) Only 1 and 4 (d) Only 1, 2 and 4

614

IES – 2004

Consider the following factors:

1. Size and shape that can be produced economically
2. Porosity of the parts produced
3. Available press capacity
4. High density

Which of the above are limitations of powder metallurgy?

(a) 1, 3 and 4 (b) 2 and 3
(c) 1, 2 and 3 (d) 1 and 2

615

Applications

- Oil-impregnated bearings made from either iron or copper alloys for home appliance and automotive applications
- P/M filters can be made with pores of almost any size.
- Pressure or flow regulators.
- Small gears, cams etc.
- Products where the combined properties of two or more metals (or both metals and nonmetals) are desired.
- Cemented carbides are produced by the cold-compaction of tungsten carbide powder in a binder, such as cobalt (5 to 12%), followed by liquid-phase sintering.

616

IES-2015 Conventional

Classify the products that are commonly produced by powder metallurgy. Give examples of each.

[10 Marks]

617

IES 2010

Consider the following parts:

1. Grinding wheel
2. Brake lining
3. Self-lubricating bearings

Which of these parts are made by powder metallurgy technique?

(a) 1, 2 and 3 (b) 2 only
(c) 2 and 3 only (d) 1 and 2 only

618

IAS – 1998

Throwaway tungsten carbide tip tools are manufactured by

(a) Forging (b) Brazing
(c) Powder metallurgy (d) Extrusion

619

IES – 2009

Which of the following cutting tool bits are made by powder metallurgy process?

(a) Carbon steel tool bits (b) Stellite tool bits
(c) Ceramic tool bits (d) HSS tool bits

620

GATE – 2011 (PI)

The binding material used in cemented carbide cutting tools is

(a) graphite
(b) tungsten
(c) nickel
(d) cobalt

621

IAS – 2003

Which of the following are produced by powder metallurgy process?

1. Cemented carbide dies
2. Porous bearings
3. Small magnets
4. Parts with intricate shapes

Select the correct answer using the codes given below:

Codes:

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1, 3 and 4

622

IES – 1997

Which of the following components can be manufactured by powder metallurgy methods?

1. Carbide tool tips 2. Bearings
3. Filters 4. Brake linings

Select the correct answer using the codes given below:

(a) 1, 3 and 4 (b) 2 and 3
(c) 1, 2 and 4 (d) 1, 2, 3 and 4

623

IES – 2001

Carbide-tipped cutting tools are manufactured by powder- metal technology process and have a composition of

(a) Zirconium-Tungsten (35% -65%)
(b) Tungsten carbide-Cobalt (90% - 10%)
(c) Aluminium oxide- Silica (70% - 30%)
(d) Nickel-Chromium- Tungsten (30% - 15% - 55%)

624

IES-2015

Consider the following statements regarding powder metallurgy :

1. Refractory materials made of tungsten can be manufactured easily.
2. In metal powder, control of grain size results in relatively much uniform structure
3. The powder heated in die or mould at high temperature is then pressed and compacted to get desired shape and strength.
4. In sintering the metal powder is gradually heated resulting in coherent bond.

Which of the above statements are correct?

(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

625

Pre - Sintering

If a part made by PM needs some machining, it will be rather very difficult if the material is very hard and strong. These machining operations are made easier by the pre-sintering operation which is done before sintering operation.

626

IAS – 2003

In parts produced by powder metallurgy process, pre-sintering is done to

(a) Increase the toughness of the component
(b) Increase the density of the component
(c) Facilitate bonding of non-metallic particles
(d) Facilitate machining of the part

627

IES-2016 Conventional

In reference to primary processes of Powder Metallurgy, explain the following:

(i) Blending

(ii) Compacting

(iii) Pre-sintering

(iv) Sintering [4 Marks]

628

Repressing

- Repressing is performed to increase the density and improve the mechanical properties.
- Further improvement is achieved by re-sintering.

629

Infiltration

- Component is dipped into a low melting-temperature alloy liquid
- The liquid would flow into the voids simply by capillary action, thereby decreasing the porosity and improving the strength of the component.
- The process is used quite extensively with ferrous parts using copper as an infiltrate but to avoid erosion, an alloy of copper containing iron and manganese is often used.

630

Impregnation

- Impregnation is similar to infiltration
- PM component is kept in an oil bath. The oil penetrates into the voids by capillary forces and remains there.
- The oil is used for lubrication of the component when necessary. During the actual service conditions, the oil is released slowly to provide the necessary lubrication.
- The components can absorb between 12% and 30% oil by volume.
- It is being used on P/M **self-lubricating bearing** components since the late 1920's.

631

Oil-impregnated Porous Bronze Bearings

632

GATE 2011

The operation in which oil is permeated into the pores of a powder metallurgy product is known as

(a) mixing

(b) sintering

(c) impregnation

(d) Infiltration

633

IAS – 1996

Which one of the following processes is performed in powder metallurgy to promote self-lubricating properties in sintered parts?

(a) Infiltration (b) Impregnation

(c) Plating (d) Graphitization

634

IES – 1998

In powder metallurgy, the operation carried out to improve the bearing property of a bush is called

(a) infiltration (b) impregnation

(c) plating (d) heat treatment

635

IES - 2014

The process of impregnation in powder metallurgy technique is best described by which of the following?

(a) After sintering operation of powder metallurgy, rapid cooling is performed to avoid thermal stresses.

(b) Low melting point metal is filled in the pores of a sintered powder metallurgy product

(c) Liquid oil or grease is filled in the pores of a sintered powder metallurgy product

(d) During sintering operation of powder metallurgy, rapid heating is performed to avoid sudden produce of high internal pressure due to volatilization of lubricant

636

IAS – 2007

Consider the following basic steps involved in the production of porous bearings:

1. Sintering
2. Mixing
3. Repressing
4. Impregnation
5. Cold-die-compaction

Which one of the following is the correct sequence of the above steps?

(a) 1 – 2 – 3 – 4 – 5 (b) 2 – 5 – 1 – 3 – 4

(d) 5 – 4 – 3 – 2 – 1 (d) 4 – 3 – 1 – 5 – 2

637

IAS – 2004

The following are the constituent steps in the process of powder metallurgy:

1. Powder conditioning
2. Sintering
3. Production of metallic powder
4. Pressing or compacting into the desired shape

Indentify the correct order in which they have to be performed and select the correct answer using the codes given below:

(a) 1-2-3-4 (b) 3-1-4-2

(c) 2-4-1-3 (d) 4-3-2-1

638

IES – 2001

Match List-I (Components) with List-II (Manufacturing Processes) and select the correct answer using the codes given below the lists:

	List I		List II
A.	Car body (metal)	1.	Machining
B.	Clutch lining	2.	Casting
C.	Gears	3.	Sheet metal pressing
D.	Engine block	4.	Powder metallurgy

Codes:	A	B	C	D		A	B	C	D
(a)	3	4	2	1	(b)	4	3	1	2
(c)	4	3	2	1	(d)	3	4	1	2

639

GATE -2008 (PI)

Match the following

Group – 1	Group -2
P. Mulling	1. Powder metallurgy
Q. Impregnation	2. Injection moulding
R. Flash trimming	3. Processing of FRP composites
S. Curing	4. Sand casting

(a) P – 4, Q – 3, R – 2, S – 1 (b) P – 2, Q – 4, R – 3, S - 1
(c) P – 2, Q – 1, R – 4, S – 3 (d) P – 4, Q – 1, R – 2, S - 3

640

Conventional Questions

- **Explain why metal powders are blended. Describe what happens during sintering.**

[IES-2010, 2 Marks]

641

Conventional Questions

Enumerate the steps involved in "powder metallurgy" process. Discuss these steps. Name the materials used in "powder metallurgy". What are the limitations of powder metallurgy? [IES-2005, 10 Marks]

642

You have to grow
from the inside out.
None can teach you,
There is no other teacher
But your own soul.

643

644

Cutting Tool Materials

By S K Mondal

Introduction

- Success in metal cutting depends on selection of the proper cutting tool (material and geometry) for a given work material.
- A wide range of cutting tool materials is available with a variety of properties, performance capabilities, and cost.
- These include:
  - High carbon Steels and low/medium alloy steels,
  - High-speed steels,
  - Cast cobalt alloys,

Contd...

- Cemented carbides,
- Cast carbides,
- Coated carbides,
- Coated high speed steels,
- Ceramics,
- Cermets,
- Whisker reinforced ceramics,
- Sialons,
- Sintered polycrystalline cubic boron nitride (CBN),
- Sintered polycrystalline diamond, and single-crystal natural diamond.

3

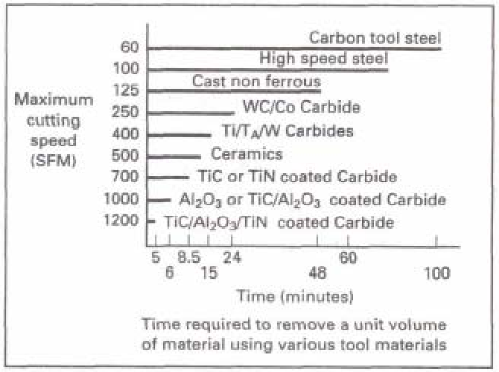


FIGURE: Improvements in cutting tool materials have reduced machining time.

4

Carbon Steels

- Limited tool life. Therefore, not suited to mass production.
- Can be formed into complex shapes for small production runs
- Low cost
- Suited to hand tools, and wood working
- Carbon content about 0.9 to 1.35% with a hardness ABOUT 62 C Rockwell
- Maximum cutting speeds about 8 m/min. dry and used upto 250°C
- The hot hardness value is low. This is the major factor in tool life.

5

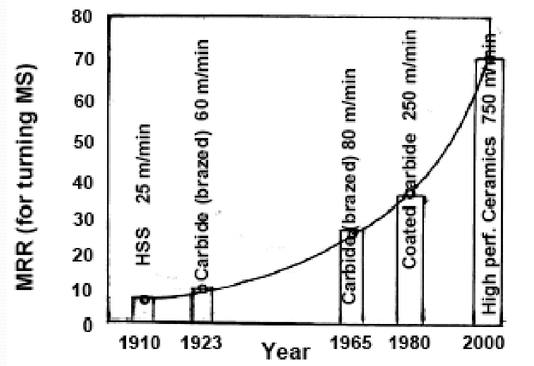


Fig. Productivity raised by cutting tool materials

6

IAS – 1997

Assertion (A): Cutting tools made of high carbon steel have shorter tool life.

Reason(R): During machining, the tip of the cutting tool is heated to 600/700°C which cause the tool tip to lose its hardness.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

7

High Speed Steel

8

High speed steel

- These steels are used for cutting metals at a much higher cutting speed than ordinary carbon tool steels.
- The high speed steels have the valuable property of retaining their hardness even when heated to red heat.
- Most of the high speed steels contain tungsten as the chief alloying element, but other elements like cobalt, chromium, vanadium, etc. may be present in some proportion.

Contd...

- With time the effectiveness and efficiency of HSS (tools) and their application range were gradually enhanced by improving its properties and surface condition through -
  - Refinement of microstructure
  - Addition of large amount of cobalt and Vanadium to increase hot hardness and wear resistance respectively
  - Manufacture by powder metallurgical process
  - Surface coating with heat and wear resistive materials like TiC , TiN , etc by Chemical Vapour Deposition (CVD) or Physical Vapour Deposition (PVD)

10

IES-2013

Vanadium in high speed steels:

(*a*) Has a tendency to promote decarburization

(*b*) Form very hard carbides and thereby increases the wear resistance of the tool

(*c*) Helps in achieving high hot hardness

(*d*) Has a tendency to promote retention of Austenite

11

IAS-1997

Which of the following processes can be used for production thin, hard, heat resistant coating at TiN, on HSS?

1. Physical vapour deposition.
2. Sintering under reducing atmosphere.
3. Chemical vapour deposition with post treatment
4. Plasma spraying.

Select the correct answer using the codes given below:

Codes:

(a) 1 and 3 (b) 2 and 3

(c) 2 and 4 (d) 1 and 4

12

18-4-1 High speed steel

- This steel contains 18 per cent tungsten, 4 per cent chromium and 1 per cent vanadium.
- It is considered to be one of the best of all purpose tool steels.
- It is widely used for drills, lathe, planer and shaper tools, milling cutters, reamers, broaches, threading dies, punches, etc.

13

IES-2003

The correct sequence of elements of 18-4-1 HSS tool is

(a) W, Cr, V

(b) Mo, Cr, V

(c) Cr, Ni, C

(d) Cu, Zn, Sn

14

IES 2007

Cutting tool material 18-4-1 HSS has which one of the following compositions?

(a) 18% W, 4% Cr, 1% V (b) 18% Cr, 4% W, 1% V

(c) 18% W, 4% Ni, 1% V (d) 18% Cr, 4% Ni, 1% V

15

IES-1993

The blade of a power saw is made of

(a) Boron steel

(b) High speed steel

(c) Stainless steel

(d) Malleable cast iron

16

Molybdenum high speed steel

- This steel contains 6 per cent tungsten, 6 per cent molybdenum, 4 per cent chromium and 2 per cent vanadium.
- It has excellent toughness and cutting ability.
- The molybdenum high speed steels are better and cheaper than other types of steels.
- It is particularly used for drilling and tapping operations.

17

Super high speed steel

- This steel is also called ***cobalt high speed steel*** because cobalt is added from 2 to 15 per cent, in order to increase the cutting efficiency especially at high temperatures.
- This steel contains 20 per cent tungsten, 4 per cent chromium, 2 per cent vanadium and 12 per cent cobalt.

18

IES-1995

The compositions of some of the alloy steels are as under:

1. 18 W 4 Cr 1 V
2. 12 Mo 1 W 4 Cr 1 V
3. 6 Mo 6 W 4 Cr 1 V
4. 18 W 8 Cr 1 V

The compositions of commonly used high speed steels would include

(a) 1 and 2 (b) 2 and 3
(c) 1 and 4 (d) 1 and 3

19

IES-2000

Percentage of various alloying elements present in different steel materials are given below:

1. 18% W; 4% Cr; 1% V; 5% Co; 0.7% C
2. 8% Mo; 4% Cr; 2% V; 6% W; 0.7% C
3. 27% Cr; 3% Ni; 5% Mo; 0.25% C
4. 18% Cr; 8% Ni; 0.15% C

Which of these relate to that of high speed steel?

(a) 1 and 3 (b) 1 and 2
(c) 2 and 3 (d) 2 and 4

20

IES-1992

The main alloying elements in high speed Steel in order of increasing proportion are

(a) Vanadium, chromium, tungsten
(b) Tungsten, titanium, vanadium
(c) Chromium, titanium, vanadium
(d) Tungsten, chromium, titanium

21

IAS-2001

Assertion (A): For high-speed turning of magnesium alloys, the coolant or cutting fluid preferred is water-miscible mineral fatty oil.

Reason (R): As a rule, water-based oils are recommended for high-speed operations in which high temperatures are generated due to high frictional heat. Water being a good coolant, the heat dissipation is efficient.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

22

IAS 1994

Assertion (A): The characteristic feature of High speed Steel is its red hardness.

Reason (R): Chromium and cobalt in High Speed promote martensite formation when the tool is cold worked.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

23

IAS – 2013 Main

Compare HSS and ceramic tools with regard to their application in high speed machining.

24

Cast cobalt alloys/Stellite

- Cast cobalt alloys are cobalt-rich, chromium-tungsten- carbon cast alloys having properties and applications in the intermediate range between high-speed steel and cemented carbides.
- Although comparable in room-temperature hardness to high-speed steel tools, cast cobalt alloy tools retain their hardness to a much higher temperature. Consequently, they can be used at higher cutting speeds (25% higher) than HSS tools.
- Cutting speed of up to 80-100 fpm can be used on mild steels.
- Cast cobalt alloys are hard as cast and cannot be softened or heat treated.
- Cast cobalt alloys contain a primary phase of Co-rich solid solution strengthened by Cr and W and dispersion hardened by complex hard, refractory carbides of W and Cr.

Contd...

25

- Other elements added include V, B, Ni, and Ta.
- Tools of cast cobalt alloys are generally cast to shape and finished to size by grinding.
- They are available only in simple shapes, such as single-point tools and saw blades, because of limitations in the casting process and expense involved in the final shaping (grinding). The high cost of fabrication is due primarily to the high hardness of the material in the as-cast condition.
- Materials machinable with this tool material include plain-carbon steels, alloy steels, nonferrous alloys, and cast iron.
- Cast cobalt alloys are currently being phased out for cutting-tool applications because of increasing costs, shortages of strategic raw materials (Co, W, and Cr), and the development of other, superior tool materials at lower cost.

26

IES 2011

Stellite is a non-ferrous cast alloy composed of:

(a) Cobalt, chromium and tungsten
(b) Tungsten, vanadium and chromium
(c) Molybdenum, tungsten and chromium
(d)Tungsten, molybdenum, chromium and vanadium

27

IAS – 2013 Main

What are the desirable properties while selecting a tool material for metal-cutting applications?

Cemented Carbide

- Carbides, which are nonferrous alloys, are also called, sintered (or cemented) carbides because they are manufactured by powder metallurgy techniques.
- Most carbide tools in use today are either straight **tungsten carbide (WC)** or multicarbides of W-Ti or W-Ti-Ta, depending on the work material to be machined.
- Cobalt is the binder.
- These tool materials are much harder, are chemically more stable, have better hot hardness, high stiffness, and lower friction, and operate at higher cutting speeds than do HSS.
- They are more brittle and more expensive and use strategic metals (W, Ta, Co) more extensively.

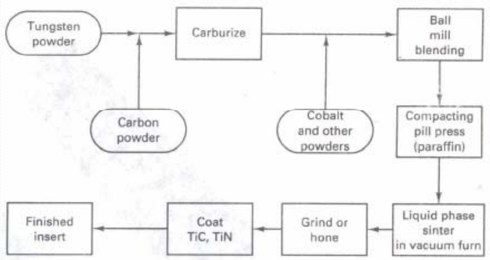
Contd...

- Cemented carbide tool materials based on TiC have been developed, primarily for auto industry applications using predominantly Ni and Mo as a binder. These are used for higher-speed (> 1000 ft/min) finish machining of steels and some malleable cast irons.
- Cemented carbide tools are available in insert form in many different shapes; squares, triangles, diamonds, and rounds.
- Compressive strength is high compared to tensile strength, therefore the bits are often brazed to steel shanks, or used as inserts in holders.
- These inserts may often have negative rake angles.

Contd...

- Speeds up to 300 fpm are common on mild steels
- Hot hardness properties are very good
- Coolants and lubricants can be used to increase tool life, but are not required.
- Special alloys are needed to cut steel

Contd...



Tungsten is carburized in a high-temperature furnace, mixed with cobalt and blended in large ball mills. After ball milling, the powder is screened and dried. Paraffin is added to hold the mixture together for compacting. Carbide inserts are compacted using a pill press. The compacted powder is sintered in a high-temperature vacuum furnace. The solid cobalt dissolves some tungsten carbide, then melts and fills the space between adjacent tungsten carbide grains. As the mixture is cooled, most of the dissolved tungsten carbide precipitates onto the surface of existing grains. After cooling, inserts are finish ground and honed or used in the pressed condition.

FIGURE 22-4 PM process for making cemented carbide insert tools.

IES-1995

The straight grades of cemented carbide cutting tool materials contain

(a) Tungsten carbide only

(b) Tungsten carbide and titanium carbide

(c) Tungsten carbide and cobalt

(d) Tungsten carbide and cobalt carbide

IAS – 1994

Assertion (A): Cemented carbide tool tips are produced by powder metallurgy.

Reason (R): Carbides cannot be melted and cast.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

The standards developed by ISO for grouping of carbide tools and their application ranges are given in Table below.

ISO Code	Colour Code	Application
P		For machining long chip forming common materials like plain carbon and low alloy steels
M		For machining long or short chip forming ferrous materials like Stainless steel
K		For machining short chipping, ferrous and non- ferrous material and non – metals like Cast Iron, Brass etc.

Table below shows detail grouping of cemented carbide tools

ISO Application group	Material	Process
P01	Steel, Steel castings	Precision and finish machining, high speed
P10	Steel, Steel castings	Turning, threading, and milling high speed, small chips
P20	Steel, steel castings, malleable cast iron	Turning, milling, medium speed with small chip section
P30	Steel, steel castings, malleable cast iron	Turning, milling, medium speed with small chip section
P40	Steel and steel casting with sand inclusions	Turning, planning, low cutting speed, large chip section
P50	Steel and steel castings of medium or low tensile strength	Operations requiring high toughness turning, planning, shaping at low cutting speeds

K01	Hard grey C.I., chilled casting, Al. alloys with high silicon	Turning, precision turning and boring, milling, scraping
K10	Grey C.I. hardness > 220 HB. Malleable C.I., Al. alloys containing Si	Turning, milling, boring, reaming, broaching, scraping
K20	Grey C.I. hardness up to 220 HB	Turning, milling, broaching, requiring high toughness
K30	Soft grey C.I. Low tensile strength steel	Turning, reaming under favourable conditions
K40	Soft non-ferrous metals	Turning milling etc.
M10	Steel, steel castings, manganese steel, grey C.I.	Turning, milling, medium cutting speed and medium chip section
M20	Steel casting, austentic steel, manganese steel, spherodized C.I., Malleable C.I.	Turning, milling, medium cutting speed and medium chip section
M30	Steel, austenitic steel, spherodized C.I. heat resisting alloys	Turning, milling, planning, medium cutting speed, medium or large chip section
M40	Free cutting steel, low tensile strength steel, brass and light alloy	Turning, profile turning, specially in automatic machines.

37

IES-1999

Match List-I (ISO classification of carbide tools) with List-II (Applications) and select the correct answer using the codes given below the Lists:

List-I	**List-II**
A. P-10	1. Non-ferrous, roughing cut
B. P-50	2. Non-ferrous, finishing cut
C. K-10	3. Ferrous material, roughing cut
D. K-50	4. Ferrous material, finishing cut

Code:	**A**	**B**	**C**	**D**		**A**	**B**	**C**	**D**
(a)	4	3	1	2	(b)	3	4	2	1
(c)	4	3	2	1	(d)	3	4	1	2

38

IES-2018

Consider the following statements:

1. HSS tools wear very rapidly, whereas in cemented carbide tools, even though hardness is retained, crater wear can occur due to solid-state diffusion.
2. Cutting tools made of Super-HSS also known as cobalt-based HSS, are made by adding 2% to 15% of cobalt which increases the cutting efficiency at heavier cuts by increasing the hot hardness and wear resistance.
3. Tool failure due to excessive stress can be minimized by providing small or negative rake angles on brittle tool materials, protecting tool tip by providing large side-cutting edge angles, and honing a narrow chamfer along the cutting edge.

Which of the above statements are correct?

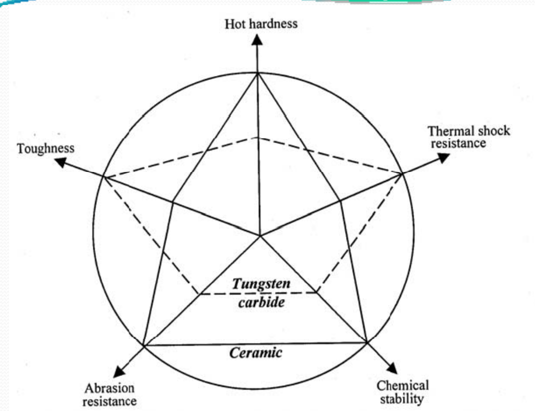
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

39

Ceramics

- Ceramics are essentially alumina (Al_2O_3) based high refractory materials introduced specifically for high speed machining of difficult to machine materials and cast iron.
- These can withstand very high temperatures, are chemically more stable, and have higher wear resistance than the other cutting tool materials.
- In view of their ability to withstand high temperatures, they can be used for machining at very high speeds of the order of 10 m/s.
- They can be operated at from two to three times the cutting speeds of tungsten carbide.

Contd...



Comparison of important properties of ceramic and tungsten carbide tools 41

- It is possible to get mirror finish on cast iron using ceramic turning.
- The main problems of ceramic tools are their low strength, poor thermal characteristics, and the tendency to chipping.
- They are not suitable for intermittent cutting or for low cutting speeds.
- Very high hot hardness properties
- Often used as inserts in special holders.

Contd...

- Through last few years remarkable improvements in strength and toughness and hence overall performance of ceramic tools could have been possible by several means which include;
  - Sinterability, microstructure, strength and toughness of Al2O3 ceramics were improved to some extent by adding TiO2 and MgO,
  - Transformation toughening by adding appropriate amount of partially or fully stabilised zirconia in Al2O3 powder,
  - Isostatic and hot isostatic pressing (HIP) – these are very effective but expensive route.

Contd...

- Introducing nitride ceramic (Si3N4) with proper sintering technique – this material is very tough but prone to built-up-edge formation in machining steels
- Developing SIALON – deriving beneficial effects of Al2O3 and Si3N4
- Adding carbide like TiC (5 ~ 15%) in Al2O3 powder – to impart toughness and thermal conductivity
- Reinforcing oxide or nitride ceramics by SiC whiskers, which enhanced strength, toughness and life of the tool and thus productivity spectacularly.
- Toughening Al2O3 ceramic by adding suitable metal like silver which also impart thermal conductivity and self lubricating property; this novel and inexpensive tool is still in experimental stage.

Contd...

- Cutting fluid, if applied should in flooding with copious quantity of fluid, to thoroughly wet the entire machining zone, since ceramics have very poor thermal shock resistance. Else, it can be machined with no coolant.
- Ceramic tools are used for machining work pieces, which have high hardness, such as hard castings, case hardened and hardened steel.
- Typical products can be machined are brake discs, brake drums, cylinder liners and flywheels.

45

IES-2016

Statement (I): Ceramics withstand very high temperatures that range from 1000°C to 1600°C.

Statement (II): Silicon carbide is an exception from among ceramics that cam withstand high temperatures.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

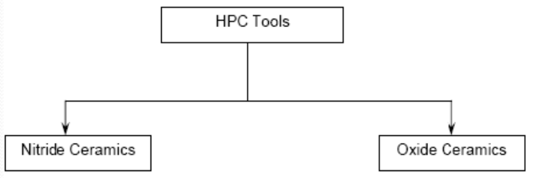
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true

46

High Performance ceramics (HPC)



Silicon Nitride	Alumina toughned by
(i) Plain	(i) Zirconia
(ii) SIALON	(ii) SiC whiskers
(iii) Whisker toughened	(iii) Metal (Silver etc)

47

IES-2013

Sialon ceramic is used as:

(*a*) Cutting tool material

(*b*) Creep resistant

(*c*) Furnace linens

(*d*) High strength

48

IES 2010

Constituents of ceramics are oxides of different materials, which are

(a) Cold mixed to make ceramic pallets

(b) Ground, sintered and palleted to make ready ceramics

(c) Ground, washed with acid, heated and cooled

(d) Ground, sintered, palleted and after calcining cooled in oxygen

49

IAS-1996

Match List I with List II and select the correct answer using the codes given below the lists:

List I (Cutting tools)	List II (Major constituent)
A. Stellite	1. Tungsten
B. H.S.S.	2. Cobalt
C. Ceramic	3. Alumina
D. DCON	4. Columbium
	5. Titanium

Codes:	A	B	C	D		A	B	C	D
(a)	5	1	3	4	(b)	2	1	4	3
(c)	2	1	3	4	(d)	2	5	3	4

50

IES-1997

Assertion (A): Ceramic tools are used only for light, smooth and continuous cuts at high speeds.

Reason (R): Ceramics have a high wear resistance and high temperature resistance.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

51

IES-1996

A machinist desires to turn a round steel stock of outside diameter 100 mm at 1000 rpm. The material has tensile strength of 75 kg/mm². The depth of cut chosen is 3 mm at a feed rate of 0.3 mm/rev. Which one of the following tool materials will be suitable for machining the component under the specified cutting conditions?

(a) Sintered carbides (b) Ceramic

(c) HSS (d) Diamond

52

IES 2007

Which one of the following is not a ceramic?

(a) Alumina

(b) Porcelain

(c) Whisker

(d) Pyrosil

53

IAS-2000

Consider the following cutting tool materials used for metal-cutting operation at high speed:

1. Tungsten carbide
2. Cemented titanium carbide
3. High-speed steel
4. Ceramic

The correct sequence in increasing order of the range of cutting speeds for optimum use of these materials is

(a) 3,1,4,2 (b) 1,3,2,4

(c) 3,1,2,4 (d) 1,3,4,2

54

IAS-2003

At room temperature, which one of the following is the correct sequence of increasing hardness of the tool materials?

(a) Cast alloy-HSS-Ceramic-Carbide
(b) HH-Cast alloy-Ceramic-Carbide
(c) HSS-Cast alloy-Carbide-Ceramic
(d) Cast alloy-HSS-Carbide-Ceramic

55

Coated Carbide Tools

- Coated tools are becoming the norm in the metalworking industry because coating , can consistently improve, tool life 200 or 300% or more.
- In cutting tools, material requirements at the surface of the tool need to be abrasion resistant, hard, and chemically inert to prevent the tool and the work material from interacting chemically with each other during cutting.
- A thin, chemically stable, hard refractory coating of TiC, TiN, or Al_2O_3 accomplishes this objective.
- The bulk of the tool is a tough, shock-resistant carbide that can withstand high-temperature plastic deformation and resist breakage.

Contd...

- The coatings must be fine grained, & free of binders and porosity.
- Naturally, the coatings must be metallurgically bonded to the substrate.
- Interface coatings are graded to match the properties of the coating and the substrate.
- The coatings must be thick enough to prolong tool life but thin enough to prevent brittleness.
- Coatings should have a low coefficient of friction so that the chips do not adhere to the rake face.
- Multiple coatings are used, with each layer imparting its own characteristic to the tool.

Contd...

- The most successful combinations are TiN/TiC/TiCN/TiN and TiN/TiC/ Al_2O_3 .
- Chemical vapour deposition (CVD) is the technique used to coat carbides.

Contd...

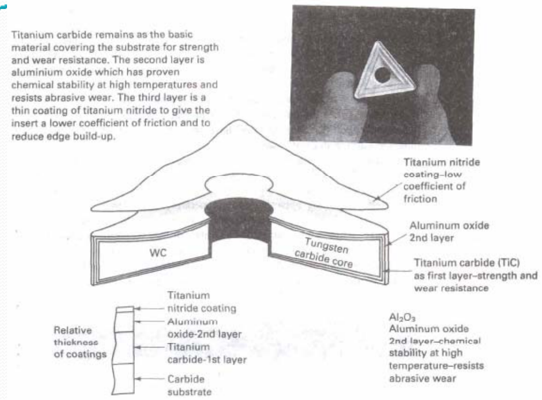


FIGURE 22-6 Triple-coated carbide tools provide resistance to wear and plastic deformation in machining of steel, abrasive wear in cast iron, and built-up edge formation.

59

IAS-1999

The coating materials for coated carbide tools, includes

(a) TiC, TiN and NaCN
(b) TiC and TiN
(c) TiN and NaCN
(d) TiC and NaCN

60

TiN-Coated High-Speed Steel

- Coated high-speed steel (HSS) does not routinely provide as dramatic improvements in cutting speeds as do coated carbides, with increases of 10 to 20% being typical.
- In addition to hobs, gear-shaper cutters, and drills, HSS tooling coated by TiN now includes reamers, taps, chasers, spade-drill blades, broaches, bandsaw and circular saw blades, insert tooling, form tools, end mills, and an assortment of other milling cutters.

Contd...

- Physical vapour deposition (PVD) has proved to be the best process for coating HSS, primarily because it is a relatively low temperature process that does not exceed the tempering point of HSS.
- Therefore, no subsequent heat treatment of the cutting tool is required.
- The advantage of TiN-coated HSS tooling is reduced tool wear.
- Less tool wear results in less stock removal during tool regrinding, thus allowing individual tools to be reground more times.

62

Cermets

- These sintered hard inserts are made by combining 'cer' from ceramics like TiC, TiN or TiCN and 'met' from metal (binder) like Ni, Ni-Co, Fe etc.
- Harder, more chemically stable and hence more wear resistant
- More brittle and less thermal shock resistant
- Wt% of binder metal varies from 10 to 20%.
- Cutting edge sharpness is retained unlike in coated carbide inserts
- Can machine steels at higher cutting velocity than that used for tungsten carbide, even coated carbides in case of light cuts.
- Modern cermets with rounded cutting edges are suitable for finishing and semi-finishing of steels at higher speeds, stainless steels but are not suitable for jerky interrupted machining and machining of aluminium and similar materials.

63

IES 2010

The cutting tool material required to sustain high temperature is

(a) High carbon steel alloys

(b) Composite of lead and steel

(c) Cermet

(d) Alloy of steel, zinc and tungsten

64

IES-2000

Cermets are

(a) Metals for high temperature use with ceramic like properties

(b) Ceramics with metallic strength and luster

(c) Coated tool materials

(d) Metal-ceramic composites

65

IES – 2003

The correct sequence of cutting tools in the ascending order of their wear resistance is

(a) HSS-Cast non-ferrous alloy (Stellite)-Carbide-Nitride

(b) Cast non-ferrous alloy (Stellite)-HSS-Carbide-Nitride

(c) HSS-Cast non-ferrous alloy (Stellite)-Nitride-Carbide

(d) Cast non-ferrous alloy (Stellite)-Carbide-Nitride-HSS

66

Diamonds

- Diamond is the hardest of all the cutting tool materials.
- Diamond has the following properties:
  - extreme hardness,
  - low thermal expansion,
  - high heat conductivity, and
  - a very low co-efficient of friction.
- This is used when good surface finish and dimensional accuracy are desired.
- The work-materials on which diamonds are successfully employed are the non-ferrous one, such as copper, brass, zinc, aluminium and magnesium alloys.
- On ferrous materials, diamonds are not suitable because of the diffusion of carbon atoms from diamond to the work-piece material.

67

Contd...

GATE – 2009 (PI)

Diamond cutting tools are not recommended for machining of ferrous metals due to

(a) high tool hardness

(b) high thermal conductivity of work material

(c) poor tool toughness

(d) chemical affinity of tool material with iron

68

- Diamond tools have the applications in single point turning and boring tools, milling cutters, reamers, grinding wheels, honing tools, lapping powder and for grinding wheel dressing.
- Due to their brittle nature, the diamond tools have poor resistance to shock and so, should be loaded lightly.
- Polycrystalline diamond (PCD) tools consist of a thin layer (0.5 to 1.5 mm) of fine grain- size diamond particles sintered together and metallurgically bonded to a cemented carbide substrate.
- The main advantages of sintered polycrystalline tools over natural single-crystal tools are better quality, greater toughness, and improved wear resistance, resulting from the random orientation of the diamond grains and the lack of large cleavage planes.

69

Contd...

- Diamond tools offer dramatic performance improvements over carbides. Tool life is often greatly improved, as is control over part size, finish, and surface integrity.
- Positive rake tooling is recommended for the vast majority of diamond tooling applications.
- If BUE is a problem, increasing cutting speed and the use of more positive rake angles may eliminate it.
- Oxidation of diamond starts at about 450°C and thereafter it can even crack. For this reason the diamond tool is kept flooded by the coolant during cutting, and light feeds are used.

70

IES-1995

Assertion (A): Non-ferrous materials are best machined with diamond tools.

Reason (R): Diamond tools are suitable for high speed machining.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

71

IES-2001

Assertion (A): Diamond tools can be used at high speeds.

Reason (R): Diamond tools have very low coefficient of friction.

(a) Both A and R are individually true and R is the correct explanation of A

(b) Both A and R are individually true but R is **not** the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

72

IES – 1999

Consider the following statements:

For precision machining of non-ferrous alloys, diamond is preferred because it has

1. Low coefficient of thermal expansion
2. High wear resistance
3. High compression strength
4. Low fracture toughness

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) 3 and 4

73

IES-1992

Which of the following given the correct order of increasing hot hardness of cutting tool material?

(a) Diamond, Carbide, HSS
(b) Carbide, Diamond, HSS
(c) HSS, carbide, Diamond
(d) HSS, Diamond, Carbide

74

IAS – 1999

Assertion (A): During cutting, the diamond tool is kept flooded with coolant.

Reason (R): The oxidation of diamond starts at about 450°C

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

75

Cubic boron nitride/Borazon

- Next to diamond, cubic boron nitride is the hardest material presently available.
- It is made by bonding a 0.5 – 1 mm layer of polycrystalline cubic boron nitride to cobalt based carbide substrate at very high temperature and pressure.
- It remains inert and retains high hardness and fracture toughness at elevated machining speeds.
- It shows excellent performance in grinding any material of high hardness and strength.

Contd...

- The operative speed range for cBN when machining grey cast iron is 300 ~400 m/min
- Speed ranges for other materials are as follows:
  - Hard cast iron (> 400 BHN) : 80 – 300 m/min
  - Superalloys (> 35 R_C) : 80 – 140 m/min
  - Hardened steels (> 45 R_C) : 100 – 300 m/min
- It is best to use cBN tools with a honed or chamfered edge preparation, especially for interrupted cuts. Like ceramics, cBN tools are also available only in the form of indexable inserts.
- The only limitation of it is its high cost.

Contd...

- CBN is less reactive with such materials as hardened steels, hard-chill cast iron, and nickel- and cobalt-based superalloys.
- CBN can be used efficiently and economically to machine these difficult-to-machine materials at higher speeds (fivefold) and with a higher removal rate (fivefold) than cemented carbide, and with superior accuracy, finish, and surface integrity.

78

IES-1994

Consider the following tool materials:

1. Carbide 2. Cermet
3. Ceramic 4. Borazon.

Correct sequence of these tool materials in increasing order of their ability to retain their hot hardness is

(a) 1,2,3,4 (b) 1,2,4,3
(c) 2, 1, 3, 4 (d) 2, 1, 4, 3

79

IES-2002

Which one of the following is the hardest cutting tool material next only to diamond?

(a) Cemented carbides
(b) Ceramics
(c) Silicon
(d) Cubic boron nitride

80

IES-1996

Cubic boron nitride

(a) Has a very high hardness which is comparable to that of diamond.
(b) Has a hardness which is slightly more than that of HSS
(c) Is used for making cylinder blocks of aircraft engines
(d) Is used for making optical glasses.

81

IES-1994

Cubic boron nitride is used

(a) As lining material in induction furnace
(b) For making optical quality glass.
(c) For heat treatment
(d) For none of the above.

IAS-1998

Which of the following tool materials have cobalt as a constituent element?

1. Cemented carbide
2. CBN
3. Stellite
4. UCON

Select the correct answer using the codes given below:

Codes:

(a) 1 and 2 (b) 1 and 3
(c) 1 and 4 (d) 2 and 3

Coronite

- Coronite is made basically by combining HSS for strength and toughness and tungsten carbides for heat and wear resistance.
- Microfine TiCN particles are uniformly dispersed into the matrix.
- Unlike a solid carbide, the coronite based tool is made of three layers;
  - the central HSS or spring steel core
  - a layer of coronite of thickness around 15% of the tool diameter
  - a thin (2 to 5 μm) PVD coating of TiCN
- The coronite tools made by hot extrusion followed by PVD-coating of TiN or TiCN outperformed HSS tools in respect of cutting forces, tool life and surface finish.

IES-1993

Match List I with List IT and select the correct answer using the codes given below the lists:

List - I (Cutting tool Material)	List - I I(Major characteristic constituent)
A. High speed steel	1. Carbon
B. Stellite	2. Molybdenum
C. Diamond	3. Nitride
D. Coated carbide tool	4. Columbium
	5. Cobalt

Codes:	A	B	C	D
(a)	2	1	3	5
(b)	2	5	1	3
(c)	5	2	4	3
(d)	5	4	2	3

IES-2003

Which one of the following is not a synthetic abrasive material?

(a) Silicon Carbide (b) Aluminium Oxide
(c) Titanium Nitride (d) Cubic Boron Nitride

IES-2000

Consider the following tool materials:

1. HSS
2. Cemented carbide
3. Ceramics
4. Diamond

The correct sequence of these materials in decreasing order of their cutting speed is

(a) 4, 3, 1, 2 (b) 4, 3, 2, 1
(c) 3, 4, 2, 1 (d) 3, 4, 1, 2

IES-1999

Match List-I with List-II and select the correct answer using the codes given below the Lists:

List I (Materials)	List II (Applications)
A. Tungsten carbide	1. Abrasive wheels
B. Silicon nitride	2. Heating elements
C. Aluminium oxide	3. Pipes for conveying liquid metals
D. Silicon carbide	4. Drawing dies

Code:	A	B	C	D
(a)	3	4	1	2
(b)	4	3	2	1
(c)	3	4	2	1
(d)	4	3	1	2

IAS-2001

Match. List I (Cutting tool materials) with List II (Manufacturing methods) and select the correct answer using the codes given below the Lists:

List I	List II
A. HSS	1. Casting
B. Stellite	2. Forging
C. Cemented carbide	3. Rolling
D. UCON	4. Extrusion
	5. Powder metallurgy

Codes:	A	B	C	D
(a)	3	1	5	2
(b)	2	5	4	3
(c)	3	5	4	2
(d)	2	1	5	3

Attrition wear

- The strong bonding between the chip and tool material at high temperature is conducive for adhesive wear.
- The adhesive wear in the rough region is called attrition wear .
- In the rough region, some parts of the worn surface are still covered by molten chip and the irregular attrition wear occurs in this region .
- The irregular attrition wear is due to the intermittent adhesion during interrupted cutting which makes a periodic attachment and detachment of the work material on the tool surface.
- Therefore, when the seizure between workpiece to tool is broken, the small fragments of tool material are plucked and brought away by the chip.

IES-1996

The limit to the maximum hardness of a work material which can be machined with HSS tools even at low speeds is set by which one of the following tool failure mechanisms?

(a) Attrition

(b) Abrasion

(c) Diffusion

(d) Plastic deformation under compression.

91

IES-2005

Consider the following statements: An increase in the cobalt content in the straight carbide grades of carbide tools

1. Increases the hardness.
2. Decreases the hardness.
3. Increases the transverse rupture strength
4. Lowers the transverse rupture strength.

Which of the statements given above are correct?

(a) 1 and 3 (b) 2 and 4

(c) 1 and 4 (d) 2 and 3

92

The End

93

Ch-1 Basics of Metal Cutting: Answers with Explanations

IES-2013 Page No.2 SlideNo.8 Ans.(c)

$$\text{Speed}(V) = \frac{\pi DN}{1000} m/\min = \frac{\pi \times 30 \times 1000}{1000} m/\min = 94.2 m/\min$$

IES-2001 Page No.2 Slide No.9 Ans. (c) For cutting brass recommended rake angle is -5 to +5 degree.

IES-1995 Page No.3 Slide No.10 Ans. (a) It is true form-cutting procedure, no rake should be ground on the tool, and the top of the tool must be horizontal and be set exactly in line with the axis of rotation of the work; otherwise, the resulting thread profile will not be correct. An obvious disadvantage of this method is that the absence of side and back rake results in poor cutting (except on cast iron or brass). The surface finish on steel usually will be poor.

GATE-1995;2008 Page No.3 Slide No.11 Ans. (a) Increasing rake angle reduces the cutting force on the tool and thus power consumption is reduced.

IES-1993 Page No.3 Slide No.12 Ans. (d) Negative rake angle increases the cutting force i.e. specific pressure. $\text{Specific pressure} = \frac{\text{Cutting force}}{\text{feed} \times \text{depth of cut}}$

IES-2005 Page No.3 Slide No.13 Ans.(b) Carbide tips are generally given negative rake angle it is very hard and very brittle material. Negative rake is used as carbides are brittle not due to hardness. Hardness and brittleness is different property

IES-2015 Page No. 3 Slide No.14 Ans.(b)

IES-2002 Page No.3 Slide No.15 Ans.(c) Carbide tools are stronger in compression.

IES-2011 Page No.3 Slide No.16 Ans. (b) The rake angle does not have any effect on flank but clearance anglehas to reduce the friction between the tool flank and the machined surface.

GATE-2008(PI) Page No.3 Slide No.17 Ans. (c) Brittle workpiece materials are hard and needs stronger tool. Tools having zero or negative rake angle provides adequate strength to cutting tool due to large lip angle.

IAS-1994 Page No.4 Slide No.20 Ans. (d)

IES-2014 Page No.4 Slide No.21 Ans. (c)

IES-2012 Page No.4 Slide No.22 Ans.(d) When cutting velocity is increased, it will lead to increase in power and temperature, and cutting force will be slightly reduce so we take as cutting forces will not be affected by the cutting velocity.Common sense will say force will increase, but if you think deeply there is no reason for increasing the force, same material same hardness, same tool same sharpness. Therefore the force will remain unaffected. But in actual practice it will reduce due to high temperature. As velocity increases power consumption will increase and temperature will increase.

IES-2006 Page No.4 Slide No.27 Ans. (d) All other tools are multi-point.

GATE-2017(PI) Page No.5 Slide No.28 Ans. (c)

IES-2012 Page No.5 Slide No.30 Ans. (b) Both are correct. We have used negative rake angles for different purpose but not for the direction of chip.In turning positive back rake angle takes the chips away from the machined surface, Whereas negative back rake angle directs the chip on to the machined surface.

IES-2003 Page No.5 Slide No.31 Ans. (b)

IES-2015 Page No.5 Slide No.32 Ans. (b)

GATE(PI)-1990 Page No.5 Slide No.33 Ans. (c)
No of chattering per cycle 360/30 = 12
No of cycle per second = 500 /60
Therefore chattering frequency is 12 x 500/60 = 100 Hz

IAS-1996 Page No.5 Slide No.34 Ans. (a)

IAS-1995 Page No.5 Slide No.35 Ans. (a) $F_y = F_t \cos\lambda = F_t \sin C_S$

IES-2010 Page No.5 Slide No.36 Ans. (c) $F_y \uparrow = F_t \cos\lambda = F_t \sin C_S \uparrow$ **(radial force)** $F_x \downarrow = F_t \sin\lambda = F_t \cos C_S \uparrow$ **(axial force)** andSCEA has no influence on cutting force i.e. tangential force. But this question is not for Orthogonal Cutting it should be turning.

IES-1995 Page No.6 Slide No.37 Ans. (c)

IES-2006 Page No.6 Slide No.38 Ans.(c) Smaller point angle results in higher rake angle.

IES-2002 Page No.6 Slide No.41 Ans. (d) Strength of a single point cutting tool depends on lip angle but lip angle also depends on rake and clearance angle.

IES-2012 Page No.6 Slide No.43 Ans. (b)

IES-2009 Page No.6 Slide No.44 Ans. (c) Large nose radius improves tool life. A sharp point on the end of a tool is highly stressed, short lived and leaves a groove in the path of cut. There is an improvement in surface finish and permissible cutting speed as nose radius is increases from zero value. But too large a nose radius will induce chatter.

IES-1995 Page No.6 Slide No.45 Ans. (c) It will increase tool cutting force.

IES-1994 Page No.7 Slide No.46 Ans. (b)

IES-2009 Page No.7 Slide No.46 Ans. (b)

IES-1993 Page No.7 Slide No.48 Ans. (b) The second item is the side rake angle. Thus 6° is theside rake angle.

ISRO-2011 Page No.7 Slide No.49 Ans. (b)

IES-2018 Page No.7 Slide No.50 Ans. (a)

GATE-2008 Page No. 7 Slide No.51 Ans.(d) We may use principal cutting edge angle or approach angle = 90 - C_S. When, principal cutting edge angle =90;then $\alpha_S = \alpha$. Don't confuse with side cutting edge angle. Side cutting edge angle is not principal cutting edge angle.

GATE-2001Page No.7 Slide No.52 Ans.(c) $\phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{0.4\cos 10}{1-0.4\sin 10} = 22.944$

GATE-2011Page No.7 Slide No.53 Ans. (b) $r = \frac{t}{t_c} = \frac{0.81}{1.8} = 0.45$

$$\phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{0.45\cos 12^o}{1-0.45\sin 12^o} = 25.90^o$$

GATE-2018 Page No.7 Slide No.54 Ans. 23.32

$$\alpha = 15°\text{ , t = 0.5 mm, } t_c = 1.25 \text{ mm, } r = \frac{t}{t_c} = \frac{0.5}{1.25} = 0.4$$

$$\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha} = \frac{0.4\cos 15°}{1-\sin 15°} \Rightarrow \phi = 23.3155° = 23.32°$$

GATE-2017Page No.8 Slide No.55 Ans. 1.494

IES-1994 Page No.8 Slide No.56 Ans. (b)Shear angle does not depends on velocity. If we double the velocity it will double the chip velocity so r will remain same. Shear angle will remain same. True feed means feed.

IES-2014 Conventional Page No.8 Slide No. 57

Ans. 18.3° $r = \frac{l_c}{l} = \frac{68.9}{\pi \times 69}$ *and* $\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha}$

GATE-2014 Page No.8 Slide No.58 Ans. 2.8 to 3.0

$$r = \frac{t}{t_c} = \frac{f\sin\lambda}{t_c}\text{(for turning)} = \frac{0.2\times\sin 90^o}{0.5} = 0.4$$

$$\phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{r\cos 0}{1-r\sin 0} = \tan^{-1} r = \tan^{-1} 0.4$$

$$\phi = 21.80^o$$

$$\text{Shear strain}(\varepsilon) = \cot\phi + \tan(\phi-\alpha) = \cot 21.80^o + \tan(21.80-0)^o = 2.9$$

IES-2004 Page No.8 Slide No.59 Ans.(d)

$$r = 0.3,\ \alpha = 10 \therefore \phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{0.3\cos 10}{1-0.3\sin 10} = 17.31^o$$

$$\text{shear strain}(\varepsilon) = \cot\phi + \tan(\phi-\alpha) = \cot 17.31^o + \tan(17.31-10)^o = 3.34$$

Without using calculator we can't solve this question.

IAS-2015 Main Page No.8 Slide No.60

$$\alpha = 10^o$$
$$t = 0.5mm$$
$$t_c = 1.125mm$$
$$r = \frac{t}{t_c} = \frac{0.5}{1.125} = 0.444$$
$$\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha} = \frac{0.444\cos 10}{1-0.444\sin 10}$$
$$\phi = 25.35^o$$
$$\gamma = \cot\phi + \tan(\phi-\alpha) = \cot 25.35^o + \tan(25.35^o - 10^o) = 2.385$$

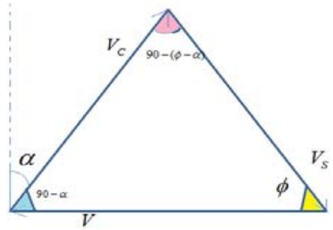
IES-2009 Page No.8 Slide No.61 Ans. (d) as rake angle is zero. shear strain $(\varepsilon) = \cot\phi + \tan\phi$

GATE-1990(PI) Page No.8 Slide No.62 Ans. (a)

$$\varepsilon = \cot\phi + \tan(\phi - 12)$$
$$\frac{d\varepsilon}{d\phi} = -\cos ec^2\phi + \sec^2(\phi-12) = 0 \text{ gives } \phi = 51^o$$

IES-2016 Page No.8 Slide No.63 Ans. (a) $\frac{V}{\cos(\phi-\alpha)} = \frac{V_s}{\cos\alpha} = \frac{V_c}{\sin\phi}$

GATE-2012 Page No.9 Slide No.64 Ans. (c)



$$r = 0.4; \alpha = 10$$
$$\phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{0.4\cos 10}{1-0.4\sin 10} = 22.94$$

from the velocity triangle;

$$\frac{V}{\sin(90-\phi+\alpha)} = \frac{V_S}{\sin(90-\alpha)}$$
$$\frac{2.5}{\sin(90-22.94+10)} = \frac{V_S}{\sin(90-10)}$$
$$V_S = 2.526m/s$$
$$\text{Shear strain rate}(\varepsilon^\cdot) = \frac{V_S}{t_S} = \frac{2.526\,m/s}{25\times 10^{-6}\,m} = 1.0104\times 10^5/s$$

IES-2004 Page No.9 Slide No.65 Ans. (b) actually 2,3 and 4 are correct.But best choice is (b)

IES-2006 Page No.9 Slide No.66 Ans. (c) Cutting torque decreases with increase in rake angle.

IES-2004 Page No.9 Slide No.67 Ans. (c)

IES-2004,ISRO-2009 Page No.9 Slide No.68 Ans. (a)

$$\frac{V_C}{\sin\phi} = \frac{V}{\sin(90+\alpha-\phi)}$$
$$V_C = \frac{35\times\sin 45}{\sin(90+15-45)} = 28.577m/\min$$

IES-2008 Page No.9 Slide No.69 Ans. (b)

Cutting ratio means chip thickness ratio, $r = 0.75$; $V = 60\,m/\min$

$$r = \frac{t}{t_C} \Rightarrow t_C = \frac{2.4}{0.75} = 3.2\,mm$$

$$\frac{V_C}{V} = \frac{\sin\phi}{\sin(90+\alpha-\phi)} = r = 0.75$$

$$V_C = 0.75 \times 60 = 45\,m/\min$$

IES-2014 Page No.9 Slide No.70 Ans. (c) f = f sinλ = 0.2 sin 90 = 0.2 mm ; t_c = 0.32 mm; cutting ratio = chip thickness ratio = t / t_c = 0.2/0.32 = 0.625 But examiner has given reciprocal value = 1.6

IES-2001 Page No.9 Slide No.71 Ans. (a) Most of the students get confused in this question. Velocity of chip sliding along the shear plane is shear velocity (V_s) and velocity of chip along rake face is chip velocity (V_c).

IES-2003 Page No.9 Slide No.72 Ans. (d)

$$t = 0.5\,mm, t_c = 0.6\,mm, \frac{V_C}{V} = r = \frac{t}{t_c} = \frac{0.5}{0.6}$$

$$or\ V_C = \frac{2\times 0.5}{0.6} = 1.66\,m/s$$

IAS-2003 Page No.10 Slide No.73 Ans. (a)

IAS-2002 Page No.10 Slide No.74 Ans. (a)

IAS-2000 Page No.10 Slide No.75 Ans. (d)

IAS-1998Page No.10 Slide No.76 Ans. (b)

$$V = \frac{\pi DN}{1000\times 60}\,m/s = \frac{\pi\times 100\times 480}{1000\times 60}\,m/s = 2.51\,m/s$$

IAS-1995 Page No.10 Slide No.77 Ans. (b) It is orthogonal cutting means depth of cut equal to uncut chip thickness. As depth of cut halved, uncut chip thickness is also halved and hence chip thickness will be halved.

GATE-2009 (PI -common data S-1) Page No.10 Slide No.78 Ans.(c)

$$t = 0.2\,mm; t_c = 0.4\,mm; \alpha = 15°$$

$$\therefore r = \frac{t}{t_c} = 0.5; \phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{0.5\cos 15°}{1-0.5\sin 15°} = 29.02°$$

Nearest option is (c)

GATE-2009 (PI- common data S-2) Page No.10 Slide No.79 Ans. (b)

$$V = 20\,m/\min; \frac{V_C}{V} = r = 0.5\ or\ V_C = 10\,m/\min$$

GATE-1995 Page No.11 Slide No.82 Ans. (b) It is multi-point cutter and mild steel is ductile material. Ductile material with multipoint cutter will produce regular shaped discontinuous chip.

IES-2007 Page No.11 Slide No.83 Ans. (b)

IES-2015 Page No.11 Slide No.84 Ans. (c)

IAS-1997 Page No.11 Slide No.85 Ans. (a)

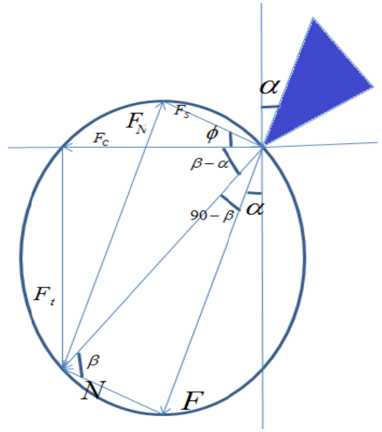
GATE-2002 Page No.11 Slide No.86 Ans. (b) Low cutting speed means long chip tool contact time. And long contact time will sufficient to form bond between chip and tool.

GATE-2009 Page No.11Slide No.87 Ans. (d) Low cutting speed means long chip tool contact time. And long contact time will sufficient to form bond between chip and tool. This micro-weld have to break due to relative motion between chip and tool. It will increase co-efficient of friction.

IES-1997Page No.11 Slide No.88 Ans. (d) Cast iron means brittle material and will form discontinuous chip. So chip breaker is not needed.

Ch-2: Analysis of Metal Cutting: Answers with Explanations

ESE-2000(conventional) Page No.12 Slide No.91 Ans.



$$\alpha = 10°, r = 0.35, t = 0.51\,mm, \text{b=3 mm},$$

$$\tau_y = 285\,N/mm^2, \mu = 0.65$$

$$\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha} = \frac{0.35\times\cos 10}{1-0.35\sin 10} = 0.3669$$

$$\phi = \tan^{-1}0.3669 = 20.152°$$

$$F_S = \tau_y\frac{bt}{\sin\phi} = 285\,N/mm^2\,\frac{3\,mm\times 0.51\,mm}{\sin 20.152^\circ}$$

$$= 1265.7\,N$$

$$\mu = \tan\beta,\ \therefore \beta = \tan^{-1}\mu = \tan^{-1}0.65 = 33.023^\circ$$

From Merchant Circle:

$$\therefore F_s = R\cos(\phi+\beta-\alpha)$$

$$\Rightarrow R = \frac{F_S}{\cos(\phi+\beta-\alpha)} = 1735.6\,N$$

(i) Cutting force (F_c): $F_c = R\cos(\beta-\alpha) = 1597.3\,N$

(ii) Radial force (F_y) =0 [This force is present in turning but it is orthogonal cutting]

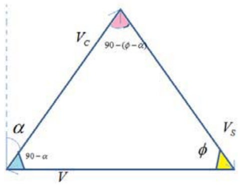
(iii) Normal force on tool (N): N = $R\cos\beta = 1455.2\,N$

(iv) Shear force (F_s):1265.7 N

Note: Shear force on tool face is friction force (F) $= R\sin\beta = 945.86\,N$

GATE-2010 (PI) linked S-1 Page No.12 Slide No.95 Ans.(a)

$\because$ Friction force is perpendicular to the cutting velocity vector that means $\alpha = 0°$



$F = 402.5N; and \frac{F}{N} = \mu = 1(given) \quad \therefore N = 402.5N$

$t = 0.2\,mm; t_c = 0.4mm,\ r = \frac{t}{t_c} = \frac{0.2}{0.4} = 0.5$

$\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha} = \frac{r\cos 0}{1-r\sin 0} = r = 0.5 ....(\because \alpha = 0°)$

$or\ \phi = \tan^{-1} r = \tan^{-1} 0.5 = 26.565°$

$\tan\beta = \mu = 1;\ \beta = 45°$

From merchant circle:

$F = R\sin\beta\ or\ R = \frac{402.5N}{\sin 45^\circ} = 569.22N$

In F_S and F_C triangle:

$F_s = R\cos(\beta-\alpha+\phi) = 569.22\times\cos(45-0+26.565)N = 180.0N$

GATE-2010 (PI) linked S-2 Page No.12 Slide No.96 Ans. (d)

$V = 2\,m/s;$

From the velocity triangle , applying sine rule;

$\frac{V}{\sin\{90-(\phi-\alpha)\}} = \frac{V_S}{\sin(90-\alpha)}$

$\frac{2}{\sin(90-26.565)} = \frac{V_S}{\sin 90}$

$V_S = 2.2361\,m/s$

$\therefore$ Heat generation at the primary shear zone will be because of shear velocity and shear force

Heat $= F_S\times V_S = 180.0N\times 2.2361\,m/s = 402.5W$

GATE-2013 linked question S-1 Page No.12 Slide No.97 Ans. (a)

From Merchant Circle if cutting force (F_C) is perpendicular to the friction force (F) then the rake angle will be zero

GATE-2013 linked question S-2 Page No.12 Slide No.98 Ans. (b)

From merchant circle;

$\because \alpha = 0$, then F, N, F_C, F_t will form a rectangle.

$F_c = N = 1500N$

$F_t = F$

GATE-2015 Page No.12 Slide No.99 Ans. 2.1

GATE-2017(PI) Page No.13 Slide No.101 Ans. (d)

IAS-1999 Page No.13 Slide No.105 Ans. (b)

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}$

$\phi = 45^\circ + \frac{20^\circ}{2} - \frac{25.5^\circ}{2} = 42.25^\circ$

GATE-1997 Page No.13 Slide No.106 Ans. (c)

Using Merchant Analysis:

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}$

$20^\circ = 45^\circ + \frac{10^\circ}{2} - \frac{\beta^\circ}{2} \Rightarrow \beta = 60^\circ$

ESE-2005(conventional)Page No.13 Slide No.107

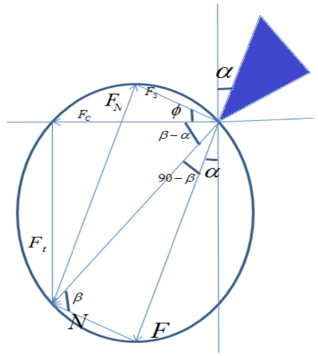
$\mu = 0.5;\ \therefore \beta = \tan^{-1}\mu = \tan^{-1} 0.5 = 26.565^\circ$

using Merchant Analysis:

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}$

$or\ \phi = 45^\circ + 5^\circ - \frac{26.565^\circ}{2} = 36.717^\circ$

$F_S = \tau_y\frac{bt}{\sin\phi} = 400N/mm^2\,\frac{2\,mm\times 0.2\,mm}{\sin 36.717^\circ} = 267.61N$



From merchant circle:

$F_s = R\cos(\phi+\beta-\alpha)$

$or\ 267.61N = R\cos(36.717^\circ + 26.565^\circ - 10^\circ)$

$or\ R = 447.6N$

$and\ F_c = R\cos(\beta-\alpha)$

$F_C = 447.6\cos(26.565^\circ - 10^\circ) = 429.02N$

$F_t = 447.6\sin(26.565^\circ - 10^\circ) = 127.61N$

GATE-2008 (PI) Linked S-1 Page No.13 Slide No.108 Ans. (d)

For minimum cutting force we have to use merchant Theory

$\alpha = 10^\circ,\ \mu = 0.7 = \tan\beta\ or\ \beta = \tan^{-1}\mu = 34.99^\circ$

Using Merchant Analysis

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}$

$\phi = 45^\circ + \frac{10^\circ}{2} - \frac{34.99^\circ}{2} = 32.5^\circ$

GATE-2008 (PI) Linked S-2 Page No.14 Slide No.109 Ans. (b)

$b = 3.6\,mm$

Calculating shear force F_s :

$F_s = \tau_y\times\frac{bt}{\sin\phi} = 460(N/mm^2)\frac{3.6\,mm\times 0.25\,mm}{\sin 32.5^\circ} = 770.52N$

Using Merchant Circle:

In triangle formed by F_s, F_n and R;

$F_s = R\cos(\phi+\beta-\alpha)$

$or\ 770.52\,N = R(N)\times\cos(32.5^\circ + 34.99^\circ - 10^\circ) \Rightarrow R = 1433.7N$

In triangle formed by F_t, F_c and R;

$F_c = R\cos(\beta-\alpha) = 1433.7\times\cos(34.99^\circ - 10^\circ) = 1299.5N$

Power $= F_C\cdot V = 1299.5N\times\frac{150}{60}m/s = 3248.8W \approx 3.25\,KW$

GATE-2014 Page No.14 Slide No.110 Ans. (d)

Using Merchant Analysis, $\phi\uparrow = 45^\circ + \frac{\alpha}{2} - \frac{\beta\downarrow}{2}$

As shear angle increases cutting force will decrease and length of shear plane decreased results chip thickness decrease.

GATE-2014 Page No.14 Slide No.111 Ans. (a)

Using Merchant Analysis, $\phi\uparrow = 45^\circ + \frac{\alpha}{2} - \frac{\beta\downarrow}{2}$

As shear angle increases area of the shear plane decreased, it results cutting force hence improve surface finish. Here option (b) is also correct but best one is option (a).

IES-2010 Page No.14 Slide No.113 Ans. (b) Merchant Analysis

IES-2005 Page No.14 Slide No.114 Ans. (a)

IES-2003 Page No.15 Slide No.119 Ans.(c)

$F_s = F_c\cos\phi - F_t\sin\phi = 900\cos 30 - 600\sin 30 = 479.4N$

IES-2014 Page No.15 Slide No.120 Ans. (b)

$F_s = F_c\cos\varphi - F_t\sin\varphi = 900\cos 11.31° - 810\sin 11.31° = 723\,N$

But we have to calculate without using calculator

$\sin 11.31° = 0.2 \text{ given } \therefore \cos 11.31° = \sqrt{1-\sin^2 11.31°} = \sqrt{1-0.2^2} = 0.98$

$900\cos 11.31° - 810\sin 11.31° = 900\times 0.98 - 810\times 0.2 = 720\,N$

IES-2000 Page No.15 Slide No.121 Ans. (a)

$F = F_c\sin\alpha + F_t\cos\alpha$

$N = F_c\cos\alpha - F_t\sin\alpha$

$\because \alpha = 0;$

· so $F = F_t = 500N$

$N = F_c = 1000N$

$\mu = \frac{F}{N} = \frac{500}{1000} = \frac{1}{2}$

IES-2016 Page No.15 Slide No.122 Ans. 0.5

$$\mu = \frac{F}{N} = \frac{F_c\sin\alpha + F_t\cos\alpha}{F_c\cos\alpha - F_t\sin\alpha} = \frac{500\sin 0 + 250\cos 0}{500\cos 0 - 250\sin 0} = 0.5$$

IES-2018 Page No.15 Slide No.123 Ans. (a)

Let us assume principal cutting edge angle $= 90^o$

$F_c = 3000\ N, \quad F_t = 1200\ N$

$$\mu = \frac{F}{N} = \frac{F_c\sin\alpha + F_t\cos\alpha}{F_c\cos\alpha - F_t\sin\alpha} = \frac{3000\sin 32^o + 1200\cos 32^o}{3000\cos 32^o - 1200\sin 32^o} = 1.37$$

GATE-2007 (PI) Linked S-1 Page No.15 Slide No.124 Ans. (a)

$F_C = 1200N; F_t = 500N; \alpha = 0^\circ$

Using the relations:

$F = F_C\sin\alpha + F_t\cos\alpha = 1200\sin 0 + 500\cos 0 = 500N$

$N = F_C\cos\alpha - F_t\sin\alpha = 1200\cos 0 - 500\sin 0 = 1200N$

$\mu = \tan\beta = \frac{F}{N} = \frac{500}{1200}$

$\therefore \beta = \tan^{-1}\frac{500}{1200} = 22.6^\circ$

GATE-2007 (PI) Linked S-2 Page No.15 Slide No.125 Ans. (b)

Orthogonal machining, t = depth of cut = 0.8 mm,

$t_c = 1.5\,\text{mm}, V = 1\,\text{m/s}$

$r = \frac{t}{t_c} = \frac{0.8}{1.5} = \frac{V_c}{V} = \frac{V_c}{1}$

$\Rightarrow V_c = 0.53\,m/s$

GATE-2011 (PI) linked S-1 Page No.15 Slide No.126 Ans. (b)

$t = 0.25\,mm;\ t_c = 0.75\,mm;\ \alpha = 0°;\ b = 2.5\ mm;\ N = 950N;\ F_t = 475N$

$r = \frac{t}{t_c} = \frac{0.25}{0.75} = 0.33333$

$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{r\cos 0}{1 - r\sin 0} = r = 0.33333$

$\phi \Rightarrow 18.435^\circ$

To calculate shear force;

as $\alpha = 0$, $N = F_c = 950\,N$

$F_s = F_c\cos\phi - F_t\sin\phi = 950\cos 18.435^\circ - 475\sin 18.435^\circ = 751.04\,N$

GATE-2011 (PI) linked S-2 Page No.16 Slide No.127 Ans. (d)

We know, $F_S = \tau_y\frac{bt}{\sin\phi};$

$751.04\,N = \tau_y\left(N/mm^2\right)\frac{2.5\,mm\times 0.25\,mm}{\sin 18.435°}$

$\Rightarrow \tau_y = 379.90\,N/mm^2$

IFS-2012 Page No.16 Slide No.128 Ans.

$d = t = 0.1\,mm,\ t_c = 0.2mm,\ b = 5\,mm,\ F_c = 500N,\ F_t = 200N,\ \alpha = 10°$

To calculate co-efficient of friction:

Using relations:

$F = F_c\sin\alpha + F_t\cos\alpha = 500\sin 10° + 200\cos 10° = 283.79N$

$N = F_c\cos\alpha - F_t\sin\alpha = 500\cos 10° - 200\sin 10° = 457.67N$

$\mu = \frac{F}{N} = \frac{283.79}{457.67} = 0.62$

To calculate shear strength;

$r = \frac{t}{t_c} = \frac{0.1\,mm}{0.2\,mm} = 0.5$

$\phi = \tan^{-1}\frac{r\cos\alpha}{1 - r\sin\alpha} = \tan^{-1}\frac{0.5\cos 10}{1 - 0.5\sin 10} = 28.334°$

Using relation;

$F_s = F_c\cos\phi - F_t\sin\phi = 500\cos 28.334° - 200\sin 28.334° = 345.18N$

Shear force(F_S) = shear strength(τ_y) × shear area $\left(\frac{bt}{\sin\phi}\right)$

$F_s = \tau_y\frac{bt}{\sin\phi} \Rightarrow 345.18 = \tau_y\times\frac{5\times 0.1}{\sin 28.334°}$

$\tau_y = 327.65\,N/mm^2$

GATE-2006 common data Q-1 Page No.16 Slide No.129 Ans. (b)

$\alpha = 15; t = 0.5mm; t_c = 0.7mm; F_c = 1200\,N; F_t = 200\,N$

$r = \frac{t}{t_c} = \frac{0.5}{0.7} = 0.7142$

$\phi = \tan^{-1}\frac{r\cos\alpha}{1 - r\sin\alpha} = \tan^{-1}\frac{0.7142\cos 15^\circ}{1 - 0.7142\sin 15^\circ} = 40.24^\circ$

$F = F_c\sin\alpha + F_t\cos\alpha = 1200\sin 15^\circ + 200\cos 15^\circ = 503.77\,N$

$N = F_c\cos\alpha - F_t\sin\alpha = 1200\cos 15^\circ - 200\sin 15^\circ = 1107.3\,N$

$\therefore \mu = \frac{F}{N} = \frac{503.77}{1107.3} = 0.455 \approx 0.46$

Alternatively

Using Merchant Theory:

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}$

$\beta = 45^\circ + \frac{15^\circ}{2} - 40.24^\circ = 24.5^\circ$

$\mu = \tan\beta = \tan 24.5^\circ = 0.456 \approx 0.46$

GATE-2006 common data Q-2 Page No.16 Slide No.130 Ans.(a)

$V = 20m/\min; F_c = 1200N; F_t = 200N(given)$

$\frac{V_c}{V} = r = \frac{t}{t_c} \quad or \frac{V_c}{20\,m/\min} = \frac{0.5}{0.7}$

$or\, V_C = 14.286\,m/\min$

Total power $= F_c \times V = 1200\,N \times \frac{20}{60}m/s = 400W$

Frictional power$= F \times V_C = 503.77N \times \frac{14.286}{60}m/s = 119.95W$

Percentage of total energy dissipated as frictional power is

$\Rightarrow \frac{F \times V_C}{F_c \times V} \times 100\% = \frac{119.95}{400} \times 100\% = 29.988\% \approx 30\%$

GATE-2006 common data Q-3 Page No.16 Slide No.131 Ans. (d)

$\varepsilon = \cot\phi + \tan(\phi - \alpha) = \cot 40.24^\circ + \tan(40.24^\circ - 15^\circ) = 1.653$

GATE-2018 Page No.16 Slide No.132 Ans. Ans. (0.4408)

t = 0.010 mm, V = 130 m/min, α = 15°, b = 6 mm, t_c = 0.015 mm

F_c = 60 N, F_t = 25 N

F= $F_c\sin\alpha$ + $F_t\cos\alpha$

= 60 sin 15° + 25 cos 15° = 39.6773 N

Ratio of frictional energy to total energy

$\frac{F.V_c}{F_c.V} = \frac{F}{F_c} \times \frac{t}{t_c} = \frac{39.6773}{60} \times \frac{0.010}{0.015} = 0.4408 \quad \left[\because \frac{t}{t_c} = \frac{V_c}{V} = r\right]$

IES-1995 Page No.16 Slide No.134Ans. (b) Tangential force accounts for 99% of the power consumption.

IES-2001 Page No.16 Slide No.135 Ans. (a)
IES-1997 Page No.17 Slide No.136 Ans. (c)
IES-1999 Page No.17 Slide No.137 Ans. (a)
GATE-2014 Page No.17 Slide No.141 Ans. 0.08 to 0.12

$t = f\sin\lambda$

$\lambda = 90^\circ - C_S = 90^\circ - 60^\circ = 30^\circ$

$t = 0.2\sin 30^\circ = 0.1\,mm$

ESE-2003(conventional) Page No.17 Slide No.142 Ans.

$\alpha = 0$; f $= 0.2mm/rev, d = 4mm, t_c = 0.8mm, dia(D) = 160mm, speed = 400rpm$

$\because$ it is a turning operation,

$F_c = 1200N$

$F_t = \frac{F_x}{\sin\lambda} = \frac{800}{\sin 75^\circ} = 828.22N$

(i) Using the force relations

F=$F_C\sin\alpha + F_t\cos\alpha = 1200\sin 0 + 828.22\cos 0 = 828.22N$

$N = F_c\cos\alpha - F_t\sin\alpha = 1200\cos 0 - 828.22\sin 0 = 1200N$

$(ii)\because$ it is a turning operation,

$t = f\sin\lambda = 0.32\sin 75^\circ = 0.3091\,mm$

$b = \frac{d}{\sin\lambda} = \frac{4}{\sin 75^\circ} = 4.1411\,mm,$

$Now,\ r = \frac{t}{t_c} = \frac{0.3091\,mm}{0.8\,mm} = 0.38638$

$\phi = \tan^{-1}\frac{r\cos\alpha}{1 - r\sin\alpha} = \tan^{-1}\frac{r\cos 0}{1 - r\sin 0} = \tan^{-1} r = \tan^{-1} 0.38638 = 21.13^\circ$

$F_s = F_c\cos\phi - F_t\sin\phi = 1200\cos 21.13 - 828.22\sin 21.13 = 820.76\,N$

$F_s = \tau_y \times \frac{bt}{\sin\phi}$

$or\ \tau_y = \frac{F_s}{\frac{bt}{\sin\phi}} = \frac{820.76}{\frac{4.1411 \times 0.3091}{\sin 21.13}} = 230.93\,N/mm^2$

$(iii)\,V = \frac{\pi DN}{60} = \frac{\pi \times 0.160 \times 400}{60} = 3.351\,m/s$

Power consumption(P)=$F_c \times V = 1200 \times 3.351W = 4.021kW$

GATE-1995(conventional) Page No.17 Slide No.143 Ans.

Given : $\alpha = 10^0$ $\quad t = f\sin\lambda = 0.15455\,mm$

$\lambda = 75^0$ $\quad r = \frac{t}{t_c} = 0.32197$

$t_c = 0.48\,mm$ $\quad \tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = 0.33586$

f = 0.16 mm/rev $\quad or\ \phi = 18.565^0$

$F_c = 500N$

$F_t = \frac{F_x}{\sin\lambda} = \frac{200}{\sin 75} = 207N$

$F = F_c \sin\alpha + F_t \cos\alpha = 500\sin 10 + 207\cos 10 = 290.68N$

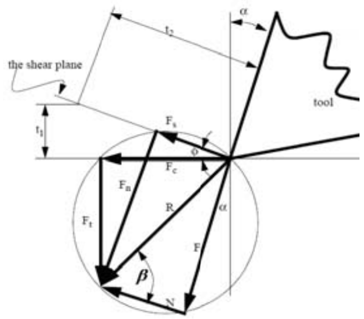
$N = F_c \cos\alpha - F_t \sin\alpha = 500\cos 10 - 207\sin 10 = 456.56N$

$\mu = \frac{F}{N} = \frac{290.68}{456.56} = 0.63667$

$\beta = \tan^{-1}\mu = 32.484^\circ$

$F_n = F_c \sin\phi + F_t \cos\phi = 500\sin 18.565 + 207\cos 18.565 = 355.42N$

$F_s = F_c \cos\phi - F_t \sin\phi = 500\cos 18.565 - 207\sin 18.565 = 408.08N$



IAS-2003(main exam) Page No.17 Slide No.144 Ans.

Given:

$\alpha_b = 7; C_S = 30; \therefore \lambda = 90^\circ - 30^\circ = 60^\circ$

$t = 2mm; b = 2.5mm; F_c = 1177N; F_t = 560N$

Using relations:

$\tan\alpha = \tan\alpha_s \sin\lambda + \tan\alpha_b \cos\lambda$

or $\tan\alpha = \tan\alpha_s \sin 60^\circ + \tan 7^\circ \cos 60^\circ$..........(*i*)

$\tan\alpha_b = \tan\alpha \cos\lambda + \sin\lambda \tan i$

or $\tan 7^\circ = \tan\alpha \cos 60^\circ + \sin 60^\circ \tan 0^\circ$

or $\alpha = 13.79^\circ$

From (*i*) $\alpha_s = 12^\circ$

Using force relations

$F = F_C \sin\alpha + F_t \cos\alpha$

$= 1177\sin 13.79 + 560\cos 13.79 = 824.44N$

$N = F_C \cos\alpha - F_t \sin\alpha = 1177\cos 13.79 - 560\sin 13.79 = 1009.6N$

$\mu = \frac{F}{N} = \frac{824.44}{1009.6} = 0.816 \quad \Rightarrow \beta = \tan^{-1}\mu = \tan^{-1} 0.816 = 39.214^\circ$

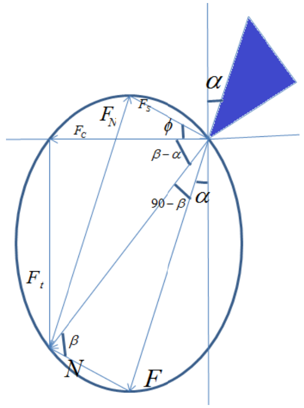
Using Merchant Theory

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2} = 45^\circ + \frac{13.79^\circ}{2} - \frac{39.214^\circ}{2} = 32.288^\circ$

Using force relation:

$F_s = F_c \cos\phi - F_t \sin\phi = 1177\cos 32.288^\circ - 560\sin 32.288^\circ = 695.87N$

Shear strength $(\tau_y) = \frac{F_s}{bt/\sin\phi} = \frac{695.87}{2\times 2.5/\sin 32.288} = 74.34N/mm^2$



GATE-2007 Page No.18 Slide No.146 Ans. (b)

$\lambda = 90^\circ; \alpha = 0^\circ$

$t = f\sin\lambda = f\sin 90^\circ = 0.24mm$

$t_c = 0.48mm$

$r = \frac{t}{t_c} = \frac{0.24mm}{0.48mm} = 0.5$

$\phi = \tan^{-1}\frac{r\cos\alpha}{1 - r\sin\alpha} = \tan^{-1}\frac{r\cos 0}{1 - r\sin 0} = \tan^{-1} r = \tan^{-1} 0.5 = 26.56^\circ$

GATE-2015 Page No.18 Slide No.147 Ans. 18.88
GATE-2015 Page No.18 Slide No.148 Ans. (a)
GATE-2016 Page No.18 Slide No.149 Ans. (b)

For an Orthogonal Turning (Orthogonal Cutting)

This question is somehow confusing, data given

for orthogonal turning but written orthogonal cutting

Principal cutting edge angle $\lambda = 90^o$

$t = f\sin\lambda$ *or* $t = 0.4\sin 90^o = 0.4mm$

$t_c = 0.8mm$

$r = \frac{t}{t_c} = \frac{0.4}{0.8} = 0.5$

Now, $\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.5\cos 22}{1 - 0.5\sin 22}$ *or* $\phi = 29.7^o$

GATE-2007 Page No.18 Slide No.150 Ans.(c)

$\lambda = 90^\circ; \alpha = 0^\circ; \phi = 25^\circ; F_c = 1000N$

We know; $F_t = \frac{F_x}{\sin\lambda} = \frac{800}{\sin 90^\circ} = 800N$

Using relations:

$F = F_c \sin\alpha + F_t \cos\alpha = 1000\sin 0 + 800\cos 0 = 800N$

$N = F_c \cos\alpha - F_t \sin\alpha = 1000\cos 0 - 800\sin 0 = 1000N$

$\mu = \frac{F}{N} = \frac{800}{1000} = 0.8$

GATE-2003(common data)S-1 Page No.18 Slide No.151 Ans. (a)

$f = 0.25mm/rev, d = 0.4mm, \alpha = 10^\circ, \phi = 27.75^\circ$

$t = f\sin\lambda = 0.25\sin 90^\circ = 0.25mm$

$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{r\cos 10^\circ}{1 - r\sin 10^\circ}$

$\tan 27.75^\circ = \frac{r\cos 10^\circ}{1 - r\sin 10^\circ}$

$r = 0.4888 = \frac{t}{t_c} = \frac{0.25}{t_c}$

$\Rightarrow t_c = 0.51138mm$

GATE-2003(common data)S-2Page No.18 Slide No.152 Ans. (d)

using Merchant Analysis;

$\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}$

$27.75^\circ = 45^\circ + \frac{10^\circ}{2} - \frac{\beta}{2} \Rightarrow \beta = 44.5^\circ$

$\mu = \tan\beta = \tan 44.5^\circ = 0.9826$

GATE-2008(common data)S-1 Page No.18 Slide No.153 Ans. (d)

$\tau_y = 250 MPa; V = 180 m/min;$

$f = 0.20 mm/rev; d = 3 mm; r = 0.5; \alpha = 7°$

$\phi = \tan^{-1}\frac{r\cos\alpha}{1-r\sin\alpha} = \tan^{-1}\frac{0.5\cos 7°}{1-0.5\sin 7°} = 27.85° \approx 28°$

We know;

$\left.\begin{matrix} d = b\sin\lambda \\ t = f\sin\lambda \end{matrix}\right] ....(\lambda = 90); d = b \,\&\, t = f$

$F_s = \tau_y \frac{bt}{\sin\phi} = 250 \times \frac{0.20\times 3}{\sin 27.85°} = 321.09N \approx 320N$

GATE-2008(common data)S-2 Page No.19 Slide No.154 Ans. (b)

Using Merchant Theory:

$\phi = 45° + \frac{7}{2} - \frac{\beta}{2} \quad \Rightarrow 28° = 45° + \frac{7°}{2} - \frac{\beta}{2} = 41°$

Using Merchant Circle:

$F_s = R\cos(\phi + \beta - \alpha)$

$320 = R\cos(28° + 41° - 7°) \Rightarrow R = 681.62N$

$F_c = R \times \cos(\beta - \alpha) = 681.62\cos(41-7) = 565.09N$

$F_t = R \times \sin(\beta - \alpha) = 681.62\sin(41-7) = 381.16N$

IES-2004 Page No.19 Slide No.156 Ans.(b)

MRR = Vfd

$= (50\times 10^3)\times 0.8 \times 1.5 mm^3/min$

$= 60000 mm^3/min$

GATE-2013 Page No.19 Slide No.157 Ans.(d)

$MRR = fdV = fd \times \frac{\pi DN}{60} mm/s = 0.25mm \times 4mm \times \frac{\pi \times 200 \times 160}{60} mm/s = 1675.5 mm^3/s$

IES-2016 Page No.19 Slide No.158 Ans. (c)

$MRR = Cross\ Section \times Axial\ Velocity$

$= \frac{\pi}{4}(D_1^2 - D_2^2)\times F$

$= \frac{\pi}{4}(10^2 - 9^2)\times 175 mm^3/min = 2611.45 mm^3/min$

$Or\ MRR = fdV = fd(\pi DN) = \pi d D_{average}(fN) = \pi d D_{average} F$

$= \pi \times 0.5 \times 9.5 \times 175\ mm^3/min = 1611.45 mm^3/min$

GATE(PI)-2018 Page No.19 Slide No.161 Ans. 630 to 641

GATE(PI)-1991 Page No.20 Slide No.163 Ans. (d)

GATE-2007 Page No.20 Slide No.164 Ans. (d)

The energy consumption per unit volume of material removal, commonly known as specific energy.

$e = \frac{Power(W)}{MRR(mm^3/s)} = \frac{F_c}{1000 fd}$

$or\ 2.0 = \frac{F_c}{1000\times 0.2 \times 2} \Rightarrow F_c = 800N$

GATE-2016(PI) Page No.20 Slide No.165 Ans. 0.001

GATE-2013(PI) common data question Page No.20 Slide No.166 Ans. (b)

$\text{Specific cutting energy} = \frac{F_C}{1000 fd} J/mm^3 = \frac{200}{1000\times 0.1 \times 1} = 2J/mm^3$

GATE-2014 Page No.20 Slide No.168 Ans. (b)

$\text{Specific pressure} = \frac{F_C}{bt} = \frac{F_C}{fd} = \frac{400}{2\times 0.1} = 2000 N/mm^2$

GATE-1992 Page No.20 Slide No.170 Ans. (b)

GATE-1993 Page No.20 Slide No.171 Ans. (b)

IES-2000 Page No.21 Slide No.172 Ans. (a)

IES-2004 Page No.21 Slide No.173 Ans. (b)

IES-2002 Page No.21 Slide No.175 Ans. (d)

chip : work piece : tool = 80 : 10 : 10

IES-1998 Page No.21 Slide No.176 Ans. (a)

IAS-2003 Page No.21 Slide No.177 Ans. (b)

IAS-2003 Page No.21 Slide No.180 Ans. (c)

IES-2011 Page No.22 Slide No.182 Ans. (c)

IES-1993 Page No.22 Slide No.183 Ans. (b)

IES- 1996 Page No.22 Slide No.184 Ans. (b)

IES- 1998 Page No.22 Slide No.187 Ans. (b) $\frac{\Delta R}{R} = G\varepsilon$

IES- 2018 Page No.22 Slide No.188 Ans. (b)

$R = 50\ \Omega, \quad \varepsilon = 0.001$

$\frac{\Delta R}{R} = G\varepsilon$

$\Delta R = RG\varepsilon = 50 \times 2.1 \times 0.001 = 0.105\ \Omega$

IAS- 2001 Page No.22 Slide No.189 Ans. (c)

FOR PSU & IES Page No.23 Slide No.190 Ans.(a) For higher sensitivity, two gauges are used for tensile strain, while two others are for compressive strain, total of which adds up to four gauges.All the four gauges in each bridge are active gauges, and the bridge fully compensates for temperature changes. For 3-D lathe dynamometer total 12 strain gauge is needed, 4 for main cutting force, 4 for Radial force and 4 for feed force.

Ch-3 Tool Life: Answers with Explanation

IES-2014 Page No.23 Slide No.194 Ans. (b) Think only the parameters which can produce cyclic stress on tool material.

IES-2010 Page No.23 Slide No.197 Ans.(a)

IES-2007, IES-2016 Page No.23 Slide No.198 Ans.(c)

IES-1994 Page No.24 Slide No.199 Ans.(b) Flank wear directly affect the component dimensions.

GATE-2014 Page No.24 Slide No.201 Ans.(c) Strain hardening don't confuse with oxide layers because if workpiece is clean then also tool will wear.

IES-2004 Page No.24 Slide No.207 Ans.(b)

GATE-2008(PI) Page No.25 Slide No.208 Ans.(b)

Solving using straight line equation:

$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1} \bullet (x - x_1)$

$1.8 - 0.8 = \frac{2 - 0.8}{60 - 10}(x - 10)$

$x = 51.666$

IES-2002 Page No.25 Slide No.213 Ans.(c) For crater wear temperature is main culprit and tool defuse into the chip material & tool temperature is maximum at some distance from the tool tip that so why crater wear start at some distance from tip.

IAS-2007 Page No.25 Slide No.214 Ans.(c)

IES-2000 Page No.25 Slide No.215 Ans.(d)

IES-1995 Page No.25 Slide No.216 Ans.(b) Crater wear occurs due to temperature mainly. And high carbon tool steel withstands least temperature 250°C. 250°C is too low for diffusion. HSS will withstand 600°C it is also low for diffusion. WC (Tungsten Carbide) tool contains cobalt as binder which can diffuse as temperature is 800°C to 900°C. Ceramics are carbide or oxides of metal it will not diffuse.

IAS-2002 Page No.26 Slide No.219 Ans.(c)

IES-1995 Page No.26 Slide No.220 Ans.(a)

IAS-1999 Page No.26 Slide No.221 Ans.(c) Chemical reaction between abrasive and workpiece material at elevated temperature and in the presence of grinding fluid.

IAS-2003 Page No.26 Slide No.223 Ans.(b)

IES-1996 Page No.26 Slide No.225 Ans.(b)

IES-2015 Page No.27 Slide No.229 Ans.(d)

IES-1992 Page No.27 Slide No.231 Ans.(d)

IES-2012 Page No.28 Slide No.235 Ans.(a)

IES-2008 Page No.28 Slide No.236 Ans. (c)

In Taylor's tool life equation is

n = 0.08 – 0.20 → for H.S.S.

n = 0.20 – 0.60 → for Carbides.

n = 0.60 – 0.80 → for Ceramics.

IES-2006 Page No.28 Slide No.237 Ans.(b)

IES-1999 Page No.28 Slide No.238 Ans.(c)

IAS-1998 Page No.28 Slide No.239 Ans.(d)

IES-2016 Page No.28 Slide No.240 Ans.(c)

GATE-2009(PI) Page No.28 Slide No.241 Ans.(a)

Using Taylor's Tool Life Equation $VT^n = C$

$$V_1T_1^n = V_2T_2^n$$

$$or\ 100\times 10^n = 75\times 30^n$$

$$or\ n = 0.2616\ \left(\text{can be solved using solve function on calculator}\right)$$

ISRO-2011 Page No.28 Slide No.242 Ans.(c)

$D = 50mm;$

$$N_1 = 284rpm; T_1 = 10\min; V_1 = \frac{\pi D\times 284}{1000} m/\min$$

$$N_2 = 232rpm; T_2 = 60\min; V_2 = \frac{\pi D\times 232}{1000} m/\min$$

Using Taylor's Tool Life Equation, $VT^n = C$

$$V_1T_1^n = V_2T_2^n$$

$$or\ \frac{\pi D\times 284}{1000}\times 10^n = \frac{\pi D\times 232}{1000}\times 60^n \quad or\ n = 0.1128$$

In the question straight line relation is mentioned which is wrong.

GATE-2004, IES-2000 Page No.28 Slide No.243 Ans.(c)

Using Taylor's Tool Life Equation, $VT^n = C$

$$V_1T_1^n = V_2T_2^n$$

$$or\ \ V\times T^n = 2V\times\left(\frac{T}{8}\right)^n\ or\ \ 8^n = 2\ or\ n = \frac{1}{3}$$

IES-1999,ISRO-2013 Page No.29 Slide No.244 Ans.(d)

Using Taylor's Tool Life Equation, $VT^n = C$

$$V_1T_1^n = V_2T_2^n$$

$$or\ \ V_1T_1^{0.25} = \left(\frac{V_1}{2}\right)T_2^{0.25}$$

$$or\ \ T_2 = 2^{\left(\frac{1}{0.25}\right)}T_1 = 16T_1$$

IAS-2016 Page No.29 Slide No.245 Ans.(d)

IAS-1995 Page No.29 Slide No.246 Ans.(d)

Using Taylor's Tool Life Equation, $VT^n = C$

$$V_1T_1^n = V_2T_2^n \quad or\ \ n = 0.25; V_2 = \frac{V_1}{2}$$

$$or\ V_1\times T_1^{0.25} = \frac{V_1}{2}\times T_2^{0.25} \quad or\ \ T_2 = 16T_1$$

GATE-2015 Page No.29 Slide No.247 Ans.0.25

IAS-2002 Page No.29 Slide No.248 Ans.(a)

Using Taylor's Tool Life Equation, $VT^n = C$

$$V_1T_1^n = V_2T_2^n \quad \left[Where,\ n = 0.5; V_2 = \frac{V_1}{2}\right]$$

$$or\ V_1T_1^{0.5} = \left(\frac{V_1}{2}\right)T_2^{0.5}$$

$$or\ T_2 = 2^{0.5}T_1 = 4T_1$$

$$\%change = \frac{T_2 - T_1}{T_1}\times 100\% = \frac{4T_1 - T_1}{T_1}\times 100\% = 300\%$$

GATE-2018 Page No.29 Slide No.247 Ans.(a)

IES-2015 Page No.29 Slide No.250 Ans.(c)

IES-2013 Page No.29 Slide No.251 Ans.(b)

Using Taylor's Tool Life Equation, $VT^n = C$

$$n = 0.25; V = 60m/\min; T = 1hr\ 21\min = 81\min$$

$$60\times 81^{0.25} = C = 180$$

IAS-1997 Page No.29 Slide No.252 Ans.(c)

Using Taylor's Tool Life Equation, $VT^n = C$

$$V_1T_1^n = V_2T_2^n$$

$$n = 0.5;\ V_1 = 18\ m/\min; T_1 = 180\min; T_2 = 45\min; V_2 = ?$$

Putting in equation:

$$\text{or}\ \ 18\times 180^{0.5} = V_2\times 45^{0.5}$$

$$or\ \ V_2 = 36m/\min$$

IES-2006 (conventional) Page No.30 Slide No.253 Ans.

Given: V_1 = 30 m/min; T_1 = 1 hr = 60 min, $V_2 = 2V_1$, T_2 = 2 min, T_3 = 30 min,
Taylor tool life equation gives

$VT^n = C$

or $V_1T_1^n = V_2T_2^n$

or $\left(\frac{T_1}{T_2}\right)^n = \left(\frac{V_2}{V_1}\right)$

taking log on both side we get

$n \ln\left(\frac{T_1}{T_2}\right) = \ln\left(\frac{V_2}{V_1}\right)$

or $n = \frac{\ln\left(\frac{V_2}{V_1}\right)}{\ln\left(\frac{T_1}{T_2}\right)} = \frac{\ln\left(\frac{2V_1}{V_1}\right)}{\ln\left(\frac{60}{2}\right)} = 0.204$

Now for = T_3 = 30 min, V_3 = ?

Here $V_1T_1^n = V_3T_3^n$

or $V_3 = \frac{V_1T_1^n}{T_3^n} = V_1 x\left(\frac{T_1}{T_3}\right)^n = 30\times\left(\frac{60}{30}\right)^{0.204} = 34.55$ m/min

$V_3 = \pi dN$

or $N = \frac{V_3}{\pi d} = \frac{34.55}{\pi\times 0.3} = 36.66$ rpm

GATE-2009 Linked Q-1 Page No.30 Slide No.254 Ans.(a)

$VT^n = C \quad V_1T_1^n = V_2T_2^n$

$60\times 81^n = 90\times 36^n$

or $\left(\frac{81}{36}\right)^n = \frac{90}{60} = 1.5$

$n = \frac{\ln 1.5}{\ln\left(\frac{81}{36}\right)} \Rightarrow n = 0.5$

$C = 60\times 81^{0.5} = 90\times 36^{0.5} = 540 = K$

GATE-2009 Linked Q-2 Page No.30 Slide No.255 Ans.(c)

Now, according to the given question $V = \frac{V_1}{2} = \frac{60}{2} = 30m/\text{min};$

$T_1 = \left(\frac{C}{V_1}\right)^{1/n}$

$T_2 = \left(\frac{C}{V_2}\right)^{1/n}$

$\frac{T_2 - T_1}{T_1} = \left(\frac{V_1}{V_2}\right)^{1/n} - 1 = (2)^{1/0.5} - 1 = 300\%$

IFS-2013 Page No.30 Slide No.256 Ans.

Using Taylor's Tool Life Equation:

$V_1T_1^n = V_2T_2^n$

or $100\times 120^n = 130\times 50^n$

or $n = 0.2997 \approx 0.3$

Now $C = 100\times 120^{0.3} = 420.49$

Tool life when cutting speed is 2.5 m/s = 2.5×60 m/min

$(2.5\times 60)T^{0.3} = 420.49$

or $T = 31.06$ min

Velocity when tool life is 80 min

$V\times 80^{0.3} = 420.49$

or $V = 112.94\ m/\min$

GATE-2010 Page No.30 Slide No.257 Ans.(a)

for Carbide → $n_1 = 1.6, K_1 = 90$

for HSS → $n_2 = 0.6, K_2 = 60$

Using Taylor's Tool Life Equation: $VT^n = C$

let cutting speed is x m/min

$x\times T_A^{0.45} = 90 \Rightarrow T_A = \left(\frac{90}{x}\right)^{1/0.45}$

and $x\times T_B^{0.3} = 60 \Rightarrow T_B = \left(\frac{60}{x}\right)^{1/0.30}$

for $T_A > T_B$

$\left(\frac{90}{x}\right)^{1/0.45} > \left(\frac{60}{x}\right)^{1/0.30}$

Solve for x using calculator, x = 26.7 m/min

GATE-2013 Page No.30 Slide No.258 Ans.(b)

for A → $n_1 = 0.45, K_1 = 3000$

for B → $n_2 = 0.3, K_2 = 200$

Using Taylor's Tool Life Equation: $VT^n = C$

let cutting speed is x m/min

$x\times T_c^{1.6} = 3000 \Rightarrow T_c = \left(\frac{3000}{x}\right)^{1/1.6}$

and $x\times T_H^{0.6} = 200 \Rightarrow T_H = \left(\frac{200}{x}\right)^{1/0.6}$

for $T_c > T_H$

$\left(\frac{3000}{x}\right)^{1/1.6} > \left(\frac{200}{x}\right)^{1/0.60}$

Solve for x using calculator, x = 39.389 m/min

GATE-2017 Page No.30 Slide No.259 Ans.(b)

Ans. 106.066

Let us assume the speed is x m/min.

$$xT_1^{0.1} = 150 \quad \Rightarrow T_1 = \left(\frac{150}{x}\right)^{\frac{1}{0.1}}$$

$$and\ xT_2^{0.3} = 300 \quad \Rightarrow T_2 = \left(\frac{300}{x}\right)^{\frac{1}{0.3}}$$

$$Now\,T_2 > T_1$$

$$or \left(\frac{300}{x}\right)^{\frac{1}{0.3}} > \left(\frac{150}{x}\right)^{\frac{1}{0.1}}$$

For solving inequality

$$\left(\frac{300}{x}\right)^{\frac{1}{0.3}} = \left(\frac{150}{x}\right)^{\frac{1}{0.1}}$$

$$or \left(\frac{300}{x}\right)^{0.1} = \left(\frac{150}{x}\right)^{0.3}$$

$$or \frac{x^{0.3}}{x^{0.1}} = \frac{150^{0.3}}{300^{0.1}}$$

$$or\ x = 106.066\,m/\min$$

EXAMPLE Page No.30 Slide No. 260 Ans.

This can be solved using regression analysis:

Using Taylor's Tool Life Equation: $VT^n = C$

taking log on both sides: $\log V + n\log T = \log C$

$or \quad \log V = \log C - n\log T$

On comparing with straight line equation, in Casio Calculator:

$y = A + Bx$

$y = \log V;\ x = \log T;\ A = \log C;\ B = -n$

T	V	X=logT	Y=logV
2.94	49.74	X_1= log2.94	Y_1= log49.47
3.90	49.23	X_2= log3.90	Y_2= log49.23
4.77	48.67	X_3= log4.77	Y_3= log48.67
9.87	45.76	X_4= log9.87	Y_4= log45.76
28.27	42.58	X_5= log28.27	Y_5= log42.58

Now on calculator,
Press mode – 2 times-then press '2'(Reg-2)
Then select the type –(lin-1)
Then start entering the values as below;
x_1, y_1 i.e. log2.94, log49.47 then press DT(M^+) it will display n =1 then press AC
x_2, y_2 i.e. log3.90, log49.23 then press DT(M^+) it will display n =2 then press AC
x_3, y_3 i.e. log4.77, log48.67 then press DT(M^+) it will display n =3 then press AC
x_4, y_4 i.e. log9.87, log45.76 then press DT(M^+) it will display n =4 then press AC
x_5, y_5 i.e. log28.27, log42.58 then press DT(M^+) it will display n =5 then press AC
After entering all values then press shift then S-VAR(on number 2),then press the right arrow 2 times then A (1) press 1 then = it will give A = 1.732
Again press the right arrow 2 times then B(2) press 2 and = it will give B = -0.07

$From\ y = A + Bx;\ A = \log C \Rightarrow C = 10^A = 54$

$B = -n = -0.07 \Rightarrow n = 0.07$

$\therefore$ equation becomes: $VT^n = C \Rightarrow VT^{0.07} = 54$

GATE-2003 Page No.30 Slide No.261 Ans.(a)

10 cutting tools produce 500 components
Therefore, 1 cutting tool will produce 50 components

$we\ know: V = \pi DNm/\min$

For the 1^{st} case:

$N = 50rpm,\ f = 0.25mm/rev$

Let t_1 be the time to produce 1 component in 1^{st} case, $t_1 = \frac{L}{fN}\min$

Tool life$(T_1) = 50components \times t_1 = 50 \times \frac{L}{f \times 50}\min$

10 cutting tools produce 122 components
Therefore, 1 cutting tool will produce 12.2 components

For the 2^{nd} case:

$N = 80rpm,\ f = 0.25mm/rev$

Let t_2 be the time to produce 1 component in 2^{nd} case, $t_2 = \frac{L}{fN}\min$

Tool life$(T_2) = 12.2components \times t_2 = 12.2 \times \frac{L}{f \times 80}\min$

Using Taylor's Tool Life Equation: $VT^n = C \Rightarrow V_1T_1^n = V_2T_2^n$

$$or\ \ \pi D \times 50 \times \left(50 \times \frac{L}{0.25 \times 50}\right)^n = \pi D \times 80 \times \left(12.2 \times \frac{L}{0.25 \times 80}\right)^n$$

$or \quad n = 0.2499 \approx 0.25$

For 3^{rd} *case*: $N = 60rpm,\ f = 0.25mm/rev$

Let t_3 be the time to produce 1 component in 3^{rd} case, $t_3 = \frac{L}{fN}\min$

Tool life$(T_3) = (x)components \times t_2 = x \times \frac{L}{f \times 60}\min$

$now, \quad V_1T_1^{0.25} = V_3T_3^{0.25}$

$$or\ \ \pi D \times 50 \times \left(50 \times \frac{L}{0.25 \times 50}\right)^{0.25} = \pi D \times 60 \times \left(x \times \frac{L}{0.25 \times 60}\right)^{0.25}$$

$$or\ \ 50 = 60 \times \left(\frac{x}{60}\right)^{0.25}$$

$or\ \ x = 28.926 \approx 29components$

GATE-2018 Page No. 31Slide No. 262 Ans. (253.53)

Time required for drilling a hole, t = $\dfrac{L}{fN}$ min

Here 'L' is const. 't' is const, N is variable.

$V_1 = \pi D \text{ x } 150 \text{ m/min}, T_1 = 300 \times \dfrac{L}{f \times 150}$ min

$V_2 = \pi D \text{ x } 300 \text{ m/min}, T_2 = 200 \times \dfrac{L}{f \times 300}$ min

$V_3 = \pi D \text{ x } 200 \text{ m/min}, T_3 = x \times \dfrac{L}{f \times 200}$ min [No. of hole is 'x']

$$V_1 T_1^n = V_2 T_2^n$$

$$\pi D \text{ x } 150 \times \left(300 \times \frac{L}{f \times 150}\right)^n = \pi D \text{ x } 300 \times \left(200 \times \frac{L}{f \times 300}\right)^n$$

$or \quad n = 0.63093$

$Now \quad V_1 T_1^n = V_3 T_3^n$

$$\pi D \text{ x } 150 \times \left(300 \times \frac{L}{f \times 150}\right)^{0.63093} = \pi D \text{ x } 200 \times \left(x \times \frac{L}{f \times 200}\right)^{0.63093}$$

or $x = 253.53$

GATE-2017 Page No. 31 Slide No. 263 *Ans. (b)*

$V_1 = \pi D \times 400\, m/\min, \quad T_1 = 20 \min$

$V_2 = \pi D \times 200\, m/\min, \quad T_2 = 60 \min$

Now using Taylor's equation

$$V_1 T_1^n = V_2 T_2^n$$

$or \quad \pi D \times 400 \times (20)^n = \pi D \times 200 \times 60^n$

$or \quad n = 0.6309$

$And, \; V_3 = \pi D \times 300\, m/\min, \quad T_3 = ?$

$V_1 T_1^n = V_2 T_2^n = V_3 T_3^n$

$\pi D \times 400 \times (20)^{0.6309} = \pi D \times 300 \times T_3^{0.6309}$

$\therefore T_3 = 31.55 \min \approx 32 \min$

GATE-1999 Page No.31 Slide No.264 Ans.(b)

$\because$ flank wear $\propto \cot\alpha$

$\therefore$ tool life $\propto \tan\alpha$

$$\% \text{ change in life} = \frac{\tan\alpha_2 - \tan\alpha_1}{\tan\alpha_1} \times 100\% = \frac{\tan 7 - \tan 10}{\tan 10} \times 100\% = -30\%$$

$\therefore$ % change in life = 30% decrease

IES-2010 Page No.31 Slide No.266 Ans.(d)
ISRO-2012 Page No.31 Slide No.267 Ans.(d)
IES-1997 Page No.31 Slide No.268 Ans.(a)
IES-1994,2007 Page No.31 Slide No.269 Ans.(c)

We know that cutting speed has the greatest effect on tool life followed by feed and depth of cut respectively. For maximizing tool life we will adjust 3- 2- 1 respectively.

IES-2008 Page No.31 Slide No.270 Ans.(a) If we increase feed rate it must increase cutting force and temperature. Therefore statement '4' is wrong.

IAS-1995 Page No.32 Slide No.271 Ans. (a) It is comparing, if we increase speed it will increase maximum temperature and depth of cut increase temperature least. That so why tool life affected mostly by velocity and least by depth of cut.

ESE-1991,IAS-2010(conventional) Page No.32 Slide No.272 Ans.

$given; VT^{0.3} f^{0.6} d^{0.3} = C$

$V = 40 m/\min; T = 60 \min; f = 0.25 mm/rev; d = 2mm$

$Putting \text{ in } equation: 40 \times 60^{0.3} \times 0.25^{0.6} \times 2^{0.3} = C \quad \Rightarrow C = 36.49$

When speed, feed & depth of cut are together increased by 25%; tool life will be

Now when V, f and d are increased by 25%

New V,f and d are: $V = 40 + 0.25 \times 40 = 50\, m/\min$

$f = 0.25 + 0.25 \times 0.25 = 0.3125 mm/rev$

$d = 2 + 0.25 \times 2 = 2.5 mm$

putting in given equation: $VT^{0.13} f^{0.6} d^{0.3} = 36.49$

$50 \times T^{0.13} \times 0.3125^{0.6} \times 2.5^{0.3} = 34.99$

$T = 2.29 \min$

When only speed is increased by 25%, rest parameters remain same; then

Now when V is increased by 25%

New V,f and d are: $V = 40 + 0.25 \times 40 = 50 m/\min, f = 0.25 mm/rev, d = 2mm$

putting in given equation: $VT^{0.13} f^{0.6} d^{0.3} = 34.99$

$or \quad 50 \times T^{0.13} \times 0.25^{0.6} \times 2^{0.3} = 34.99$

$or \; T = 10.779 \min$

When only feed is increased by 25% , rest parameters remain same; then tool life

Now when f is increased by 25%

New V,f and d are: $V = 40 m/\min, f = 0.25 + 0.25 \times 0.25 = 0.3125 mm/rev, d = 2mm$

putting in given equation: $VT^{0.13} f^{0.6} d^{0.3} = 36.49$

$or \; 40 \times T^{0.13} \times 0.3125^{0.6} \times 2^{0.3} = 36.49$

$or \; T = 21.41 \min$

When only depth of cut is increased by 25%, rest parameters remain same; then

Now when d is increased by 25%

New V,f and d are: $V = 40 m/\min, f = 0.25 mm/rev, d = 2 + 0.25 \times 2 = 2.5 mm$

putting in given equation: $VT^{0.13} f^{0.6} d^{0.3} = 36.49$

$or \; 40 \times T^{0.13} \times 0.25^{0.6} \times 2.5^{0.3} = 36.49$

$or \; T = 35.844 \min$

GATE-2016 Page No.32 Slide No.273 Ans. (b)

$45 \times 30^{0.14} \times 0.35^{0.7} \times 2^{0.4} = C = 45.84$

$V_1 = 45 \times 1.25 = 56.25 m/\min$

$T_1 = ?$

$f_1 = 0.35 \times 1.25 = 0.4375 mm$

$d_1 = 2.0 \times 1.25 = 2.5 mm$

$$T_1^{0.14} = \frac{45.84}{56.25 \times 0.4375^{0.7} \times 2.5^{0.4}} = 1.007538$$

$T_1 = 1.055 \approx 1.06$

GATE-2017(PI) Page No.32 Slide No. 274 Ans. Range (80 to 84)
IES-2016 Conventional Page No.32 Slide No. 275 Ans. *n = 0.160964*, C = 72.43

IES-2010 Page No.32 Slide No.279 Ans.(a)
IAS-2003 Page No.33 Slide No.280 Ans.(a)

IES-2014 Page No.33 Slide No.286 Ans.
IES-1996 Page No.34 Slide No.289 Ans.(b)
IES-2009(conventional) Page No.34 Slide No.294 Ans.

$T_c = 3\min, Tool\ regrind\ time(T_r) = 3\min, C_m = Rs.0.50/\min$

Depriciation cost $= Rs.5.0, n = 0.2; C = 60$

Using the equation for optimum tool life for minimum cost

$$T_o = \left(T_c + \frac{C_t}{C_m}\right)\left(\frac{1-n}{n}\right)$$

$C_t = C_m \times T_r +$ Depriciation cost

$C_t = Rs.0.50/\min\times 3\min + Rs.5.0 = Rs.6.5/regrind$

Putting in equation:

$$T_o = \left(3 + \frac{6.5}{0.50}\right)\left(\frac{1-0.2}{0.2}\right) = 64\min$$

Using Taylor's Tool Life Equation: $V_oT_o^n = C$

$V_o(64)^{0.2} = 60\ or\ V_o = 26.11\,m/\min$

GATE-2014 Page No.34 Slide No.295 Ans. 5.9 to 6.1min

$T_c = 1.5\min; n = 0.2$

Using optimum tool life equation for maximum productivity:

$$\mathrm{T}_o = T_c\left(\frac{1-n}{n}\right) or\ T_o = 1.5\left(\frac{1-0.2}{0.2}\right) = 6\min$$

ESE-2001(conventional) Page No.34 Slide No.296

$V_1 = 50m/\min; T_1 = 45\min; V_2 = 100m/\min; T_2 = 10\min; T_c = 2\min$

Using Taylor's Tool Life Equation: $VT^n = C \Rightarrow V_1T_1^n = V_2T_2^n$

$50\times 45^n = 100\times 10^n \quad or\ n = 0.46,\ C = 50\times 45^{0.46} = 288$

Using equation of optimum tool life:

$$T_o = T_c\left(\frac{1-n}{n}\right) = 2\left(\frac{1-0.46}{0.46}\right) = 2.34$$

Again Using Taylor's Tool Life Equation: $V_oT_o^n = C$

$V_o \times 2.34^{0.46} = 288 \quad or\ V_o = 195m/\min$

IAS-2011(main) Page No.34 Slide No.297 Ans.

$T_c = 9\min; n = 0.5; C = 100$

Using optimum tool life equation for max productivity:

$$T_o = T_c\left(\frac{1-n}{n}\right) \quad or\ T_o = 9\left(\frac{1-0.5}{0.5}\right) = 9\min$$

Using Taylor's Tool Life Equation: $V_oT_o^n = C,\ V_o \times 9^{0.5} = 100\ or V_o = 33.33\,m/\min$

GATE-2016 Page No.35 Slide No.301 Ans. 57.91 m/min

$Total\,Cost(C_t) = Metal\,Cutting\,Cost(C_m) + Tooling\,Cost(C_t)$

$$C_t = \frac{18C}{V} + \frac{270C}{VT} \quad \left[Now\ T = \left(\frac{150}{V}\right)^{1/0.25} = \left(\frac{150}{V}\right)^4\right]$$

$$C_t = \frac{18C}{V} + \frac{270C}{V\left(\frac{150}{V}\right)^4}$$

$$\frac{dC_t}{dV} = -\frac{18C}{V^2} + \frac{270C\times 3V^2}{(150)^4} = 0 \quad or\ V = 57.91\,m/\min$$

GATE-2005 Page No.35 Slide No.302 Ans.(a)
IAS-2007 Page No.35 Slide No.303-304 Ans.(b)
IES-2011 Page No.35 Slide No.305 Ans.(d)
IES-1999 Page No.36 Slide No.307 Ans.(c)
IES-1998 Page No.36 Slide No.308 Ans.(c)
IAS-2002 Page No.36 Slide No.309 Ans.(c)

The minimum cost criterion will give a lower cutting speed i.e. lower prodeuction rate, while the maximum production rate criteria will result higher cutting speed i.e. higher cost per piece as it reduces tool life.

IAS-1997 Page No.36 Slide No.310 Ans.(b) it is less than one but very close to each other so 0.1 is not possible.

IES-2000 Page No.36 Slide No.311 Ans.(a)

IES-2004 Page No.36 Slide No.312 Ans.(a) To improve MRR = fdv i.e. productivity we can increase velocity or feed. but increase in velocity will reduce the tool drastically so will increase cost more than feed.

IES-2002 Page No.36 Slide No.313 Ans.(c)

IAS-2007 Page No.36 Slide No.314 Ans.(a) At optimum cutting speed for the minimum cost of machining gives low production rate.

IES-2010 Page No.36 Slide No.315 Ans.(d) After some time cutting speed will be so that tool changing time will be significant.

IES-2012 Page No.37 Slide No.320 Ans.(d)

IAS-1996 Page No.37 Slide No.321 Ans.(d) Machinability is a comparative measure not absolute.

IES-1992 Page No.38 Slide No.327 Ans.(a) large grain means soft workpiece material.

IAS-2000 Page No.38 Slide No.329 Ans.(a) Built up edge protects the cutting edge of the tool from wear, So tool life increased but it changes the geometry of the cutting.

IES-1992 Page No.38 Slide No.333 Ans.(a)

IES-2007,2009 Page No.39 Slide No.334 Ans.(a) Machinability: Machinability can be tentatively defined as 'ability of being machined' and more reasonably as 'ease of machining'.

Such ease of machining or machining characters of any tool-work pair is to be judged by:

- Magnitude of the cutting forces
- Tool wear or tool life
- Surface finish
- Magnitude of cutting temperature
- Chip forms

ISRO-2007 Page No.39 Slide No.335 Ans.(a) But All of the above are machinability criteria. We have to select best option that so why chosen (a)

IES-2003 Page No.39 Slide No.336 Ans.(c) Free-machining steels are basically carbon steels that have been modified by an alloy addition to enhance machinability. Sulfur, lead, bismuth, selenium, tellurium, and phosphorus have all been added to enhance machinability. Sulfur (0.08 to 0.33%) combines with manganese (0.7 to 1.6%) to form soft manganese sulfide inclusions. These act as discontinuities in the structure which serve as sites to form broken chips. The inclusions also provide a built-in lubricant that prevents formation of a built-up edge on the cutting tool and imparts an altered cutting geometry.

IES-2009 Page No.39 Slide No.337 Ans.(a) Sulphur, Lead and Phosphorous are added to steel which when added to Manganese forms Manganese sulphide etc. which has low shear strength.

IES-1998 Page No.39 Slide No.338 Ans.(c) It is CNC machine, dimensional accuracy and surface finish are prime factor.

IES-1996 Page No.39 Slide No.339 Ans.(d) smaller shear angle means higher force.

IES-1996 Page No.39 Slide No.340 Ans.(b)
IES-1995 Page No.39 Slide No.341 Ans.(c)

IES-1992 **Page No.40** **Slide No.343** **Ans. (b)** Titanium is very reactive and the chips tend to weld to the tool tip leading to premature tool failure due to edge chipping. Almost all tool materials tend to react chemically with titanium.

Titanium's work-hardening characteristics are such that titanium alloys demonstrate a complete absence of "built-up edge". Because of the lack of a stationary mass of metal (BUE) ahead of the cutting tool, a high shearing angle is formed. This causes a thin chip to contact a relatively small area on the cutting tool face and results in high loads per unit area. These high forces, coupled with the friction developed by the chip as it passes over the cutting area, result in a great increase in heat on a very localized portion of the cutting tool. All this heat (which the titanium is slow to conduct away), and pressure, means that tool life can be short, especially as titanium has a tendency to gall and weld to the tool surface.

IES-1995 **Page No.40** **Slide No.345** **Ans. (a)** Titanium high cost and need 10 times much energy than steel to produce.Light weight, strong, corrosion resistant, properties between steel and aluminium.

IES-2002 **Page No.40** **Slide No.347** **Ans. (b)**
IAS-1996 **Page No.40** **Slide No.348** **Ans. (d)**
IES-1999 **Page No.40** **Slide No.349** **Ans. (d)**

$$we\ know: h_c = \frac{f^2}{8R}$$

When $f_1 = 2f$, and h_c remains the same; $\frac{f^2}{8R} = \frac{f_1^2}{8R_1}$ or $\frac{f^2}{8R} = \frac{4f}{8R_1} \Rightarrow R_1 = 4R$

GATE-1997 **Page No.40** **Slide No.350** **Ans. (a)**

$$h = 5\mu m = 5\times10^{-6} m; R = 1.8mm = 1.8\times10^{-3} m$$

$$we\ know: h = \frac{f^2}{8R} \quad or\ 5\times10^{-6} = \frac{f^2}{8\times1.8\times10^{-3}} or\ f = 2.68\times10^{-4} m/rev = 0.268mm/rev$$

GATE-2007(PI) **Page No.40** **Slide No.351** **Ans.(a)**

$$f = 1mm/rev; SCEA = 30°; ECEA = 10°$$

$$\text{Using formula: } h = \frac{f}{\tan SCEA + \cot ECEA} = \frac{1}{\tan 30 + \cot 10} = 0.16mm$$

GATE-2018(PI) **Page No.41** **Slide No.352** **Ans. (8.4 to 8.7)**

GATE-2005 **Page No.41** **Slide No.353** **Ans. (b)**

$$\text{Using formula:} h = \frac{f}{\tan SCEA + \cot ECEA}$$

$$h_P = \frac{f}{\tan 30 + \cot 8} \ and \ h_Q = \frac{f}{\tan 15 + \cot 8}$$

$$\therefore \frac{h_P}{h_Q} = \frac{(\tan 15 + \cot 8)}{(\tan 30 + \cot 8)}$$

IES-1993,ISRO-2008 **Page No.41** **Slide No.354** **Ans. (c)** Surface roughness is directly dependent on square of feed. Slow cutting results in formation of built-up edge, but after certain speed the finish remains same.Rake angle has noticeable effect at slow speeds, but its effect is small at speeds, used for finish machining. So f has maximum effect.

IES-2006 **Page No.41** **Slide No.355** **Ans. (a)** refer previous question
GATE-2014(PI) **Page No.41** **Slide No.356** **Ans.**
GATE-2010(PI) **Page No.41** **Slide No.357** **Ans. (b)**

For increasing surface finish means reduce roughness we have to increase nose radius and reduce feed. Here MRR remains same therefore feed remains same only nose radius can be changed.

GATE-2017 **Page No.41** **Slide No.358** **Ans. (a)**

For triangular surface profile

$$R_a = \frac{h}{4} = \frac{20}{4} = 5\mu m$$

IES-2001 **Page No.42** **Slide No.361** **Ans. (c)**
IES-2012 **Page No.42** **Slide No.362** **Ans. (b)**

Ch-4: Limit, Tolerance & Fit: Answers with Explanations

For PSU **PageNo.43** **Slide No.9** **Ans.(b)**
ISRO-2010 **Page No.44** **Slide No.10** **Ans.(b)**
GATE-2010,ISRO-2012 **Page No.44** **Slide No.13** **Ans.(d)**

upper limit = 35-0.009 = 34.991mm

lower limit = 35-0.025 = 34.975mm

Fundamental Deviation = basic size-nearer limit = 35-34.991= 0.009mm

Tolerance = upper limit-lower limit = 34.991 - 34.975 = 0.016mm

GATE-1992 **Page No.44** **Slide No.14** **Ans.(a)**

Tolerance of shaft A=100.1-99.9=0.2

Tolerance of shaft B=0.1001-0.0999=0.0002

So, tolerance of shaft A > tolerance of shaft B

Never confused with relative errors because we even don't know the actual dimensions of all product. we can't calculate error.

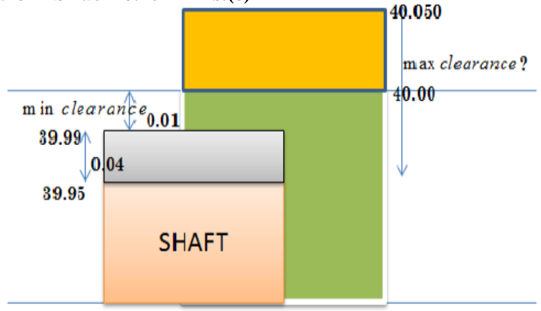
GATE-2004 **Page No.44** **Slide No.15** **Ans.(c)**

Maximum clearance = Higher limit of hole – lower limit of shaft
= 25.020-24.990 = 0.03 mm = 30 microns

IES-2005 **Page No.44** **Slide No.16** **Ans.(c)**

Since basic size is 20mm so, minimum rejection will be of the batch having mean diameter 20mm. Due to natural variations dimensions of the component will increase and decrease same from basic size.

GATE-2007 **Page No.45** **Slide No.20** **Ans.(c)**

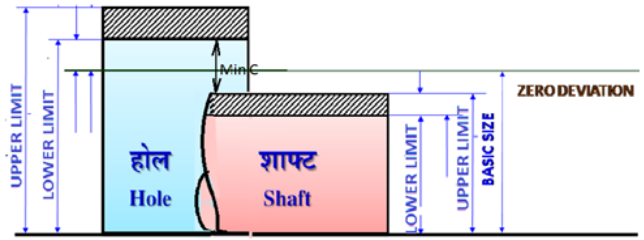


max clearance = upper limit of hole - lower limit of shaft = 40.50-39.95 = 0.1 mm

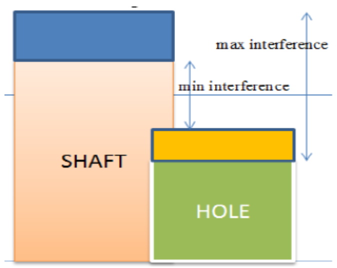
GATE-2015 **Page No.45** **Slide No.21** **Ans.(b)**This being an clearance fit , so minimum clearance will be

Min C= LL of hole –UL of Shaft

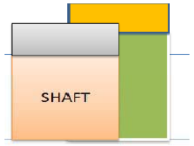
Min C = 25.020-25.005 mm = 0.015 mm



IES-2015 **Page No.45** **Slide No.22** **Ans.(a)**
IES-2015 **Page No.45** **Slide No.25** **Ans.(c)**Allowance is the minimum clearance between shaft and hole.
IES-2011 **Page No.45** **Slide No.27** **Ans.(a)**
IES-2013 **Page No.46** **Slide No.28** **Ans.(d)**
GATE-2005 **Page No.46** **Slide No.29** **Ans.(a)**



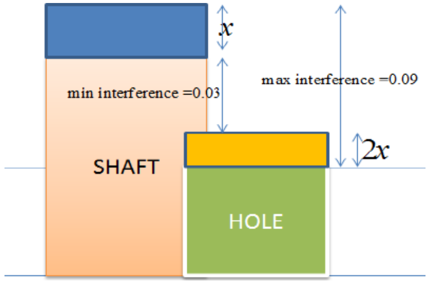
IES-2014 **Page No.46** **Slide No.30** **Ans. (c)**
IES-2015 **Page No.46** **Slide No.31** **Ans. (c)**
IES-2017 **Page No.46** **Slide No.32** **Ans. (c)**
GATE-2011 **Page No.46** **Slide No.33** **Ans.(c)**



GATE -2012 Same Q in GATE-2012 (PI) **Page No.46** **Slide No.34** **Ans.(c)**

Maximum Interference = Maximum size of shaft – Minimum size of hole
= (25 + 0.04) – (25 + 0.02) mm = 20 µm

IAS-2011(main) **Page No.46** **Slide No.35** **Ans.**



Using unilateral hole base system;

Min clearance = 0.03 mm; Max clearance = 0.09 mm; Basic size = 20 mm

Refering the figure: $2x + 0.03 + x = 0.09$ or $x = 0.02\,mm$

$\therefore$ size of hole: lower limit = 20 mm

upper limit $= 20 + 2x = 20 + 2 \times 0.02 = 20.04$ mm

size of shaft: Lower limit = 20.04 + 0.03 = 20.07 mm

upper limit $= 20.07 + x = 20.07 + 0.02 = 20.09$ mm

GATE -2018 (PI) **Page No.46** **Slide No.36** **Ans.(d)** For interference fit Lower limit of shaft will be greater than upper limit of hole. Therefore value of x should be less than 0.03 mm and only one option are there (d).

IES-2007 **Page No.47** **Slide No.37** **Ans.(a)**

For clearance fit Maximum metal condition of shaft will be smaller than minimum metal condition of the hole. (a) S_{max}=50.000, H_{min}=50.005 so $S_{max}<H_{min}$

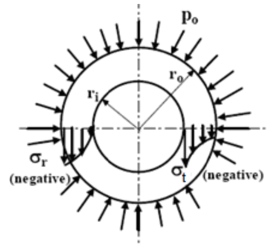
ISRO-2011 **Page No.47** **Slide No.38** **Ans.(c)**
IES-2006 **Page No.47** **Slide No.39** **Ans.(d)**
IES-2009 **Page No.47** **Slide No.40** **Ans.(d)**
IES-2008 **Page No.47** **Slide No.41** **Ans.(d)**

An interference fit creates stress state in the shaft therefore "2" is wrong.

IES-2015 **Page No.47 Slide No.42** **Ans. (d)**

It is thick cylinder under external pressure.

Distribution of radial and circumferential stresses within the cylinder wall when only external pressure acts



IES-2004 **Page No.47** **Slide No.43** **Ans.(b)**
GATE-2001 **Page No.48** **Slide No.46** **Ans.(b)**
GATE-1998 **Page No.48** **Slide No.47** **Ans.(c)**
IES-2012 **Page No.48** **Slide No.48** **Ans.(b)**
ISRO-2010 **Page No.48** **Slide No.50** **Ans.(c)**

It is transition fit, Using formula of minimum clearance

Min clearance = upper limit of shaft - lower limit of hole = -0.02 mm

Here Minimum clearance is negative i.e. maximum inteference occur.

Actually in transition fit no min clearance is there. Theoretically minimum clearance is negative of maximum interference.

ISRO-2008 **Page No.49** **Slide No.56** **Ans.(c)**
IES-2005 **Page No.49** **Slide No.57** **Ans.(c)**
IES-2005 **Page No.49** **Slide No.60** **Ans.(c)**
GATE-2014 **Page No.51** **Slide No.73** **Ans.(d)**
IES-2008 **Page No.51** **Slide No.74** **Ans.(a)** All statements are wrong. 50 mm is not hole diameter it is basic size. And examiner ask INCORRECT not correct options. Therefore all options are incorrect.

IES-2006(conventional) **Page No.51** **Slide No.75** **Ans.**

Basic size = 100 mm; $D = \sqrt{D_1 \times D_2}$

$= \sqrt{80 \times 120} = 97.97\,mm$

Fundamental deviation of shaft

$= -5.5D^{0.41} = -36\ \mu m$

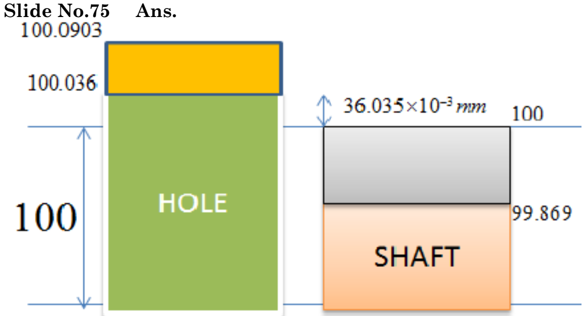
$\therefore$ Fundamental deviation of $hole = +36\ \mu m$

$i = 0.45D^{\frac{1}{3}} + 0.001D = 2.1711\,\mu m$

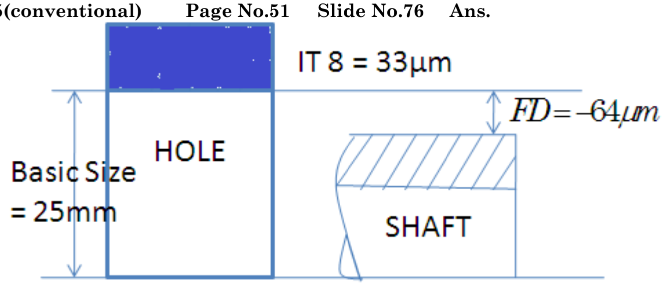
$IT8 = 25i = 25 \times 2.17\,\mu m = 54\,\mu m$

$IT10 = 64i = 64 \times 2.17\,\mu m = 139\ \mu m$

Allowance = min clearance = 36 µm



IES-2015(conventional) **Page No.51** **Slide No.76** **Ans.**



Geometric mean diameter(D) = $\sqrt{18\times30} = 23.238mm$

Standard tolerance unit (i) = $0.45\times\sqrt[3]{D} + 0.001\times D = 1.3074\mu m$

Tolerance of hole = 25i = $33\mu m = 0.033mm$

Tolerance of shaft = 40i = $52\mu m = 0.052mm$

Fundamental deviation of shaft d = $-16D^{0.44} = -64\mu m = -0.064mm$

Fundamental deviation of hole H = zero

LL of hole = BS =25mm

UL of hole = BS + Tolerance = 25.033mm

UL of shaft = BS +FD = 25- 0.064mm = 24.936mm

LL of shaft = UL - tolerance = 24.936-0.052 = 24.884 mm

Selected Question Page No.51 Slide No.77 Ans.

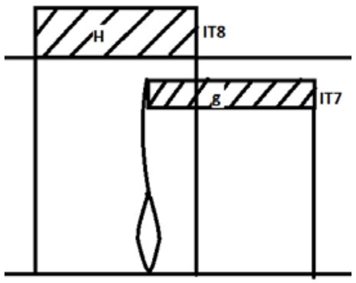
Geometric mean diameter (D) $=\sqrt{50\times80} = 63$ mm

Standard tolerance unit (i) = $0.45\sqrt[3]{D} + 0.001D = 0.45\sqrt[3]{63} + 0.001\times63 = 1.853\ \mu m$

Tolerance for hole H8 (IT8) = 25 i = $25\times1.853\ \mu m = 46\mu m = 0.046\ mm$

Tolerance for shaft g7 (IT7) = 16 i = $16\times1.853\ \mu m = 30\mu m = 0.030\ mm$

Fundamental deviation of shaft 'g' is$=-2.5\ D^{0.34} = -2.5\times63^{0.34}\mu m = -0.010\ mm$



Lower limit of hole = Basic size = 75 mm

Upper limit of hole = LL of hole + Tolerance of hole = 75 + 0.046 mm =75.046 mm

Upper limit of shaft = Basic size – fundamental deviation = 75 – 0.01 =74.99 mm

Lower limit of shaft = UL of shaft – Tolerance of shaft = 74.99 – 0.03 = 74.96 mm

Maximum clearance = UL of hole – LL of shaft = 75.046 – 74.96 mm = 0.086 mm

Minimum clearance = LL of hole – UL of shaft = 75 – 74.99 = 0.01 mm

As minimum clearance is positive it is a clearance fit.

IES-2002 Page No.51 Slide No.78 Ans.(c)

GATE-2009 Page No.51 Slide No.79 Ans.(a)

60 mm diameter lies in the diameter step of 50-80mm. Therefore

Geometric mean diameter, $D = \sqrt{D_{min}\times D_{max}} = \sqrt{50\times80} = 63.246\,mm$

Fundamental tolerance unit $(i) = (0.45D^{1/3}+0.001D)\,\mu m$

$= [0.45(63.246)^{1/3} + 0.001(63.246)] = 1.859\,\mu m = 0.00186\,mm$

$For\ IT8 = 25i\ \ = 25\times0.00186 = 0.04646\,mm$

Fundamental deviation for 'f' shaft, $= -5.5D^{0.41} = -5.5[63.246]^{0.41} = -0.030115mm$

GATE-2008(PI) Page No.51 Slide No.80 Ans.(c) Without calculating we can choose option (c) as fundamental deviation is zero therefore LL = Basic size = 25.000 mm

But proper calculation is

$D = \sqrt{D_1\times D_2} = \sqrt{18\times30} = 23.23\,mm$

$i = 0.45D^{\frac{1}{3}} + 0.001D = 1.3076\mu m = 1.3076\times10^{-3}\,mm$

$For\ IT8 = 25i = 0.0326mm$

upper limit of hole = basic size + tolerance = 25+0.0326=25.032mm

$\because$ hole base system so, lower limit = basic size=25mm

GATE-2000 Page No.51 Slide No.81 Ans.(d)

Hole: Lower limit = Basic size = 25 mm

Higher limit = lower limit + tolerance = 25 + 0.033 = 25.033 mm

Shaft: Higher limit = basic size – fundamental deviation = 25 – 0.04 = 24.96 mm

Lower limit = Higher limit – tolerance = 24.96 – 0.033 = 24.927 mm

Therefore Maximum clearance = Higher limit of hole – lower limit of shaft

= 25.033 – 24.927 = 0.106 mm = 106 microns

GATE-2003 Page No.52 Slide No.82 Ans.(b)

$\because$ diametric steps are not given we take given dia as the basic diameter only.

$i = 0.45\sqrt[3]{D} + 0.001D = 1.34\mu m = 1.34\times10^{-3}\,mm$

$For\ IT7 = 16i = 16\times1.34\times10^{-3} = 0.021\,mm$

$\because$ it is a shaft base system:

Upper limit = basic size=25.00 mm

Lower limit = Upper limit – tolerance = 25.00 - 0.021=24.978 mm

GATE-2010(PI) Page No.52 Slide No.83 Ans.(d)

Fundamental deviation of all the bore is zero.

For IT7, Tolerance = 16i = 0.021 mm

For IT8, Tolerance = 25i = 0.033 mm

Therefore i = 0.021/16 mm = 0.033/25 mm

For IT6, Tolerance = 10i = 0.013 mm

Use formula $10\times1.6^{IT_n - IT_6}$

GATE-2016(PI) Page No.52 Slide No.84 Ans. (b) All are shaft basis system.

GATE-1996,IES-2012 Page No.52 Slide No.86 Ans.(d)

Remember

H7 with p6, s6: Interference fit

H7 with k6, n6: Transition fit

All other fits are clearance fit.

IES-2000 Page No.52 Slide No.87 Ans.(b)

ISRO-2008 Page No.52 Slide No.90 Ans.(a)

GATE-2003 Page No.53 Slide No. 94 Ans.(b)

P = 35+0.08mm

Q = 12.00+0.02mm

$R = 13.0^{+0.04}_{-0.02} = 13.01\pm0.03$

Now all have same bilateral tolerance, so

P = Q + W + R

Considering dimension

$\Rightarrow\quad 35 = 12 + W + 13.01$

w = 9.99mm

Tolerance are probabilities and not the absolute value on any part, at least one section must be there that treated as sink, and tolerance of sink will be cumulative sum of all tolerances.

$\therefore\quad$ Tolerance = 0.08 + 0.02 + 0.03 = 0.13

GATE-1997 Page No.53 Slide No. 95 Ans.(d)

$S = P+Q+R+T \quad or \quad T = S-P-Q-R \quad or\ T_{min} = S_{min} - P_{max} - Q_{max} - R_{max}$

GATE-2015 Page No.53 Slide No. 96 Ans.(d)

LL of L_4 = LL of L_1 –UL of L_2 –UL of L_3

= 21.99-10.005-10.005=1.98mm

UL of L_4 = UL of L_1 –LL of L_2 –LL of L_3

= 22.01-9.995-9.995=2.02mm

GATE-2007(PI) Page No.53 Slide No.97 Ans.(d)

Before plating the hole size will be bigger ,

Maximum limit will correspond to min thickness;so,

$\text{min thickness} = 2\times\left(10\times10^{-3}\right)mm = 0.02mm$

Max limit = max size of hole + min thickness = 30.050+0.02=30.07 mm

Minimum limit will correspond to max thickness;so,

$\text{max thickness} = 2\times\left(15\times10^{-3}\right)mm = 0.03mm$

Min limit = min size of hole + max thickness = 30.010+0.03=30.04 mm

GATE-2013 Page No.53 Slide No.98 Ans. (d)

Upper limit of pin = 25.020 mm

Lower limit of pin = 25.010 mm

Max thickness of plating $=2\times0.032=0.064$ mm

Min thickness of plating $=2\times0.028=0.056$ mm

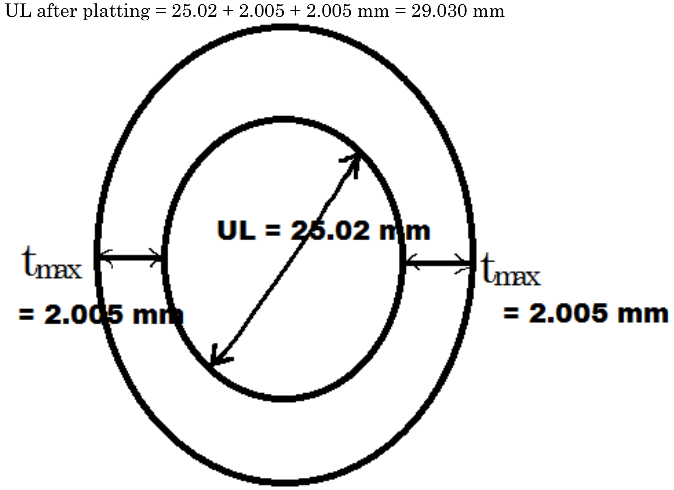
Minimum size will correspond to max thickness

Size of GO-Guage = Lower limit of pin + Max thickness of plating

Size of GO-Guage = 25.020+ 2x0.032 = 25.084 mm

GATE-2017 Page No.53 Slide No.99 Ans. 29.030

GO ring gauge will inspect maximum metal conditions i.e. UL of shaft i.e. Largest size after platting.
UL after platting = 25.02 + 2.005 + 2.005 mm = 29.030 mm



GATE-2000 Page No.54 Slide No.100 Ans.(a) It is a case of tolerance sink. Final product will be tolerance sink because due to the errors in the block and due to the errors in the cutter locations both errors will affect.

GATE-2017 Page No.54 Slide No.101 Ans.5

According to Root Sum Square or RSS model

$$\sigma_a = \sqrt{\sum_{i=1}^{n}\sigma_i^2}$$

σ_a = assembly tolerance standard deviation

σ_i = ith component tolerance standard deviation

Here $\sigma_P = 3\ \mu m$ and $\sigma_Q = 4\ \mu m$

$$\sigma_a = \sqrt{\sigma_P^2 + \sigma_Q^2} = \sqrt{3^2 + 4^2} = 5\,\mu m$$

ISRO-2008 Page No.54 Slide No.103 Ans.(c)

GATE-2014 Page No.55 Slide No.109 Ans.(d)

Lower limit of hole = 25-0.015=24.958 mm

lower limit of GO-Guage = 24.985 mm

Work tolerance = 10% of guage tolerance = 10% of $(2\times0.015)=0.003$ mm

Upper limit of GO- Guage $= 24.985_{0}^{+0.003}\ mm$

GATE-2004 Page No.55 Slide No.110 Ans. (None)

Higher limit of hole = 20.05 mm
Lower limit of hole = 20.01 mm
Work tolerance = 20.05 – 20.01 = 0.04 mm
Gauge tolerance = 10% of work tolerance = 0.004 mm

Therefore, Dimension of 'GO' gauge $= 20.01^{0.004}_{0}\ mm$

Dimension of 'NOT GO' gauge $= 20.05^{0.004}_{0}\ mm$

GATE-2015 Page No.55 Slide No.111 Ans.(b, c and d are correct.)
GATE-1995 Page No.55 Slide No.112 Ans.(b)
GATE – 2006, VS-2012Page No.55 Slide No.113 Ans.(c)
PSU Page No.56 Slide No.118 Ans.(c)
GATE-2016 Page No.56 Slide No.119 Ans. (a)

Ch-5 Measurement of Lines & Surface: Answers with Explanations

GATE-2017(PI) Page No.57 Slide No.130 Ans. (c)

ISRO-2010 Page No.58 Slide No.139 Ans.(a) The vernier reading should not be taken at its face value before an actual check has been taken for zero.

ISRO-2008 Page No.58 Slide No.140 Ans.(c) Least count = 0.5/25 = 0.02 mm

ISRO-2009, 2011 Page No.58 Slide No.143 Ans.(a)

$$\text{Total dimension= pitch}\times\text{No.of div} + \frac{Pitch}{\text{No.of div in thimble}}\times reading$$

0.5x5 + (0.5/50) x 12 = 2.62 mm

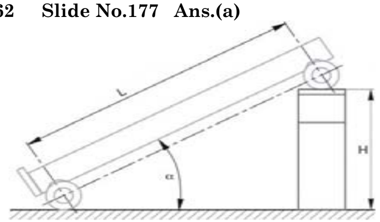
GATE-2008 Page No.59 Slide No.147-148 Ans.(c) If there is axial intersection R_P must not equal to R_Q

GATE-2014(PI) Page No.59 Slide No.149-150 Ans. (d)

ISRO-2010 Page No.60 Slide No.157 Ans.(c)A measuring device of a standard size that is used to calibrate other measuring instruments.

ISRO-2008 Page No.60 Slide No.158 Ans.(d) Primary standards are used for calibration only. In workshop it has no use.

GATE-2007(PI) **Page No.60** **Slide No.161** **Ans.(d)**During the measurement, a comparator is able to give the deviation of the dimension from the set dimension. Cannot measure absolute dimension but can only compare two dimensions. (Rest all the options will give reading of the dimension measured it will not compare)
ISRO-2011 **Page No.62** **Slide No.176** **Ans.(c)**A sine bar is specified by the distance between the centre of the two rollers
GATE-2012(PI) **Page No.62** **Slide No.177** **Ans.(a)**



$$L = 250\,mm;\, H + r = 100\,mm;\, (Diameter\ d = 20\,mm\ or\ r = 10\,mm)\ or\ H = 90\,mm$$

$$\theta = \sin^{-1}\left(\frac{H}{L}\right) = \sin^{-1}\left(\frac{90}{250}\right) = 21.1^o$$

GATE-2018 **Page No.62** **Slide No.178** **Ans.** *(57.782)*

$$\theta = 27^o32' = \left\{27 + \left(\frac{32}{60}\right)\right\}^o = 27.533°$$

In sine bar,

$$\sin\theta = \frac{H}{L}$$

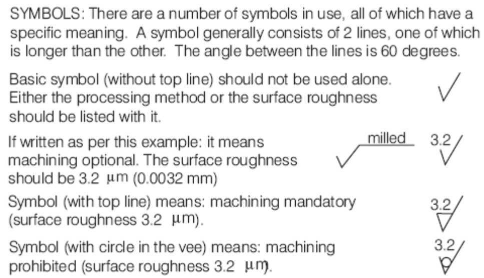
$$\sin 27.533° = \frac{H}{125}$$

$$H = 57.782\,mm$$

GATE-2011(PI) **Page No.63** **Slide No.188** **Ans.(a)**

$$\text{Best Wire Size}: d = \frac{p}{2}\sec\frac{\alpha}{2} = \frac{2.5}{2}\sec\left(\frac{60}{2}\right) = 1.443\,mm$$

GATE-2013 **Page No.63** **Slide No.189** **Ans.(none) refer formula**
IES-2017(Pre) **Page No.64** **Slide No.190** **Ans(c)**
GATE-2011(PI) **Page No.64** **Slide No.191** **Ans.(None)**
IES-2012 **Page No.65** **Slide No.201** **Ans.** Refer slides for theory
GATE-2017(PI) **Page No.65** **Slide No.205** **Ans.(b)**
IES-1992 **Page No.66** **Slide No.210** **Ans.(b)**
GATE-2018(PI) **Page No.66** **Slide No.214** **Ans. (b)**
GATE-2007(PI) **Page No.66** **Slide No.215** **Ans. (d)** Concentricity will refer centre. Runout need datum. Runout is the total variation that the reference surface can have, when the part is rotated around the datum's true axis. Perpendicularity need one reference surface from where it can be checked.
GATE-2016(PI) **Page No.67** **Slide No.220** **Ans.**Ans. 2 μm (Range 2.0 to 2.0)
ISRO-2011 **Page No.67** **Slide No.222** **Ans.(d)**
IES-2006 **Page No.67** **Slide No.223** **Ans.(d)**
IES-2007 **Page No.67** **Slide No.224** **Ans.(c)**Lay direction: is the direction of the predominant surface pattern produced on the workpiece by the tool marks.
IES-2008 **Page No.67** **Slide No.225** **Ans.(b)**Lay – directional of predominant surface texture produced by machining operation is called Lay.
IES-2010 **Page No.68** **Slide No.226** **Ans.(b)**
IES-2008 **Page No.68** **Slide No.227** **Ans.(c)**


SYMBOLS: There are a number of symbols in use, all of which have a specific meaning. A symbol generally consists of 2 lines, one of which is longer than the other. The angle between the lines is 60 degrees.

Basic symbol (without top line) should not be used alone. Either the processing method or the surface roughness should be listed with it.

If written as per this example: it means machining optional. The surface roughness should be 3.2 μm (0.0032 mm)

Symbol (with top line) means: machining mandatory (surface roughness 3.2 μm).

Symbol (with circle in the vee) means: machining prohibited (surface roughness 3.2 μm).

ISRO-2010 **Page No.68** **Slide No.228** **Ans.(a)**
GATE-2018(PI) **Page No.69** **Slide No.243** **Ans.(a)**
GATE-2016 **Page No.70** **Slide No.245** **Ans.675**

The distance of air gap between two successive fringes is given by $= \frac{n\lambda}{2}$

For 1 mm fringe gap we need 450 nm

$\therefore$ For 1.5 mm fringe gap we need 450×1.5 nm = 675 nm

GATE-2003 **Page No.70** **Slide No.252** **Ans.(a)**

$$\Delta h = \frac{n\lambda l}{2}$$

$$(1.002 - 1.000)\times 10^{-1}cm = \frac{n \times 0.0058928 \times 10^{-1}cm \times 10^{-1}cm}{2}$$

$$n = 0.678 / cm$$

So for both fringes=$2 \times n = 1.357 \approx 2\ fringes$

GATE-2011(PI) **Page No.71** **Slide No.255** **Ans.(c)**

$$Parallelism\ Error = \frac{(14-10)}{4} \times 0.5086\ \mu m = 0.5086\ \mu m$$

Ch-6 Miscellaneous of Metrology: Answers with Explanations

GATE-1998 **Page No.72** **Slide No.263** **Ans. (c)**Autocollimator isan optical instrument for non-contact measurement of small angles or small angular tilts of a reflecting surface
GATE-2009(PI) **Page No.72** **Slide No.264** **Ans. (a)**
GATE-2014 **Page No.72** **Slide No. 265** **Ans. (b)**Autocollimator is also measure flatness.
ISRO-2010 **Page No.72** **Slide No.268** **Ans. (b)**In optical square two mirrors are placed at an angle of 45° to each other and at right angles to the plane of the instrument. Angle between the first incident ray and the last reflected ray is 90°.Two mirrors may be replaced by two prisms.
IES-1998 **Page No.73** **Slide No.271** **Ans. (d)**
GATE-2014 **Page No.73** **Slide No. 274** **Ans. (c)** Laser interferometer is widely used to check and calibrate geometric features of machine tools during their assembly
GATE-1992 **Page No.74** **Slide No.282** **Ans. (b)**
GATE-2004 **Page No.74** **Slide No. 285** **Ans. (b)**
GATE-1995 **Page No.74** **Slide No. 287** **Ans. (b)**
GATE-2010 **Page No.75** **Slide No.291** **Ans. (a)**

$\tan\theta = \frac{10}{30}$

$\theta = 18.434$

Also,

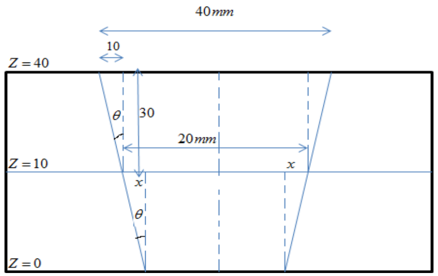
$\tan\theta = \frac{x}{10}$

$\tan 18.434 = \frac{x}{10}$

$x = 3.334$

$\therefore$ diameter at z = 0 is $(20-2x)$

$\therefore$ diameter $= (20 - 2\times 3.334) = 13.336$



GATE-2008(PI) Page No.75 Slide No. 292 Ans. (d)

$\tan\frac{\theta}{2} = \frac{C_2A}{5+15.54+8} = \frac{3}{28.54}$

$\frac{\theta}{2} = 6.006$

$\theta = 12.001$

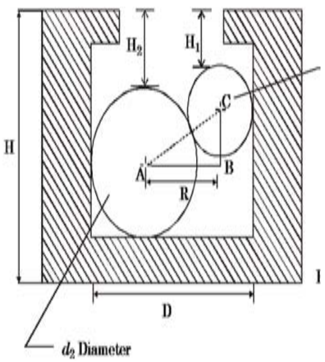
GATE-2014 Page No.75 Slide No. 293

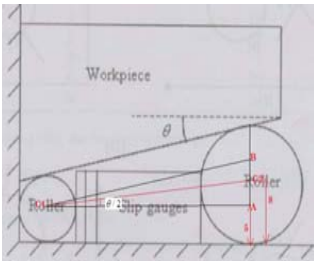
BC = (H2 + d2/2) – (H1 + d1/2) = 35.55 + 60/2 - 20.55 – 40/2 = 25 mm

AC = 60/2 + 40/2 = 50 mm

$AB = \sqrt{(50^2 - 25^2)} = 43.3$

D = 60/2 + 43.30 + 40/2 = 93.30 mm





GATE-2016 Page No.75 Slide No.294 Ans. (d)

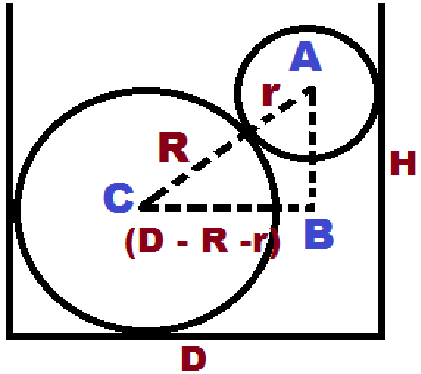
$AB = \sqrt{(R+r)^2 - (D-R-r)^2}$

$= \sqrt{(R+r+D-R-r)(R+r-D+R+r)}$

$= \sqrt{2D(R+r) - D^2}$

$H = R + AB + r$

$= R + r + \sqrt{2D(R+r) - D^2}$



GATE-2018(PI) Page No.75 Slide No.295 Ans. 1.7

Ch-7 Metal Forming: Answers with Explanations

GATE-1995 Page No. 76 Slide No.9 Ans. (b) If the specimen is stressed slightly beyond the yield point and unloaded then the phenomena of strain hardening takes place as a result of which strength increases.

IES-2013 Page No.77 Slide No. 10 Ans. (b)

IES-2018 Page No.77 Slide No. 13 Ans. (b)

IES-2016 Page No.77 Slide No. 14 Ans. (a)

IES-2016 Page No.78 Slide No. 27 Ans. (a)

Mechanical properties of the material is depends on grain size.

Due to plastic deformation grain gets elongated.

IES-2011 Page No.79 Slide No. 31 Ans. (b) If cold worked it will improve mechanical properties.

GATE-2003 Page No.79 Slide No. 32 Ans. (c) If working below Rx temp then it is cold-working process

GATE-2002, ISRO-2012 Page No. 79 Slide No. 33 Ans. (d)

ISRO-2010 Page No. 79 Slide No. 34 Ans. (d) Annealing is used to induce ductility, soften material, relieve internal stresses, refine the structure by making it homogeneous, and improve cold working properties.Normalization is an annealing process in which a metal is cooled in air after heating.

IES-2006 Page No.79 Slide No.35 Ans. (c) When a metal is heated & deformed under mechanical force, an energy level will reached when the old grain structure (which is coarse due to previous cold working) starts disintegrating. Simultaneously, an entirely new grain structure (equi-axed, stress free) with reduced grain size Starts forming. This phenomenon is known as "recrystallisation". Never be confused with Annealing because in the last stage of annealing grain growth takes place. So no reduction in grain size.

IES-2004 Page No. 79 Slide No. 36 Ans. (b) For cold working metal should have high ductility.

IES-2009 Page No. 80 Slide No.37 Ans. (d) Strength increases due to grain refinement.

IES-2008 Page No. 80 Slide No. 38 Ans. (b)

IES-2008 Page No. 80 Slide No. 39 Ans. (a)

Advantages of Cold Forming vs. Hot Working:

- Better accuracy, closer tolerances
- Better surface finish
- Strain hardening increases strength and hardness
- Grain flow during deformation can cause desirable directional properties in product
- No heating of work required (less total energy)

Dis-advantages of Cold Forming

- Equipment of higher forces and power required
- Surfaces of starting work piece must be free of scale and dirt
- Ductility and strain hardening limit the amount of forming that can be done
- In some operations, metal must be annealed to allow further deformation
- In other cases, metal is simply not ductile enough to be cold worked

IES-2004 Page No. 80 Slide No.40 Ans. (c) During deformation, a portion of the deformation energy becomes stored within the material in the form of additional dislocations and increased grain boundary surface area.
IES-2003 Page No. 80 Slide No. 41 Ans. (a)
IES-2000 Page No. 80 Slide No. 42 Ans. (d) Annealing required.
ISRO-2009 Page No. 80 Slide No. 43 Ans. (a)
IES-1997 Page No. 80 Slide No. 44 Ans. (c)

- Phenomenon where ductile metals become stronger and harder when they are deformed plastically is called strain hardening *or* work hardening.
- During plastic deformation, dislocation density increases. And thus their interaction with each other resulting in increase in yield stress.

IES-1996 Page No. 80 Slide No. 45 Ans. (c) Cold working increases the strength and hardness of the material due to strain hardening. Strength, fatigue, and wear properties are improved through strain hardening.
IES-2006 Page No. 81 Slide No. 46 Ans. (d) Should be above the recrystallisation temperature.
IES-1992 Page No. 81 Slide No. 47 Ans. (c)

- Annealing relieves the stresses from cold working – three stages: recovery, recrystallization and grain growth.
- During recovery, physical properties of the cold-worked material are restored without any observable change in microstructure.
- Grain growth follows complete crystallization if the material is left at elevated temperatures.
- Grain growth does not need to be preceded by recovery and recrystallization; it may occur in all polycrystalline materials.

IAS-1996 Page No. 81 Slide No. 48 Ans. (c) For Mild Steel, recrystallisation temp is of the order of 1000^0C
IAS-2004 Page No. 81 Slide No. 49 Ans. (a)
IAS-2002 Page No. 81 Slide No. 50 Ans. (b) Ulta hai. Assertion reason me hona chahiye**.**
IES-2008 Page No. 81 Slide No. 51 Ans. (d) Malleability- It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. A malleable material should be plastic but it is not essential to be so strong. Lead, soft steel, wrought iron, copper and aluminium are some materials in order of diminishing malleability.
GATE -2017 Page No.81 Slide No.52 Ans.(c) In metal forming mechanical properties of materials will increase due to improvement in grain.

Ch-8 Rolling: Answers with Explanations

GATE -2013 Page No.82 Slide No.55 Ans.(c) Bi axial compression and frictional force between roller and workpiece produces shear stress
IAS-2001 Page No.82 Slide No.60 Ans.(c) Rolling means hot working it will not show work hardening
ISRO-2006 Page No.82 Slide No.63 Ans.(c) You may confused with Forging but forging is hot working, but Cold rolling (cold working) is mentioned therefore answer will be (c). In cold working product will be stronger. If we compare cold forging and cold rolling then cold forging produce stronger components.
ISRO-2009 Page No.83 Slide No.66 Ans.(a)
IES-2006 Page No.83 Slide No.71 Ans.(c) A continuous form of three-point bending is roll bending, where plates, sheets, and rolled shapes can be bent to a desired curvature on forming rolls**.**
IES – 1992, GATE-1992(PI) Page No.84 Slide No.78 Ans.(b) Since brittle materials cannot handle plastic deformation.
IES – 1993, GATE-1989(PI) Page No.84 Slide No.79 Ans.(d)

- *Thread rolling* is used to produce threads in substantial quantities. This is a cold-forming process operation in which the threads are formed by rolling a thread blank between hardened dies that cause the metal to flow radially into the desired shape. Because no metal is removed in the form of chips, less material is required, resulting in substantial savings. In addition, because of cold working, the threads have greater strength than cut threads, and a smoother, harder, and more wear-resistant surface is obtained.
- One obvious characteristic of a rolled thread is that its major diameter always is greater than the diameter of the blank. *When an accurate class of fit is desired, the diameter of the blank is made about*

0.002 inch larger than the thread-pitch diameter. If it is desired to have the body of a bolt larger than the outside diameter of the rolled thread, the blank for the thread is made smaller than the body.

IAS-2007 Page No.85 Slide No.87 Ans.(d)
IAS -2003 Page No.85 Slide No.88 Ans.(b)
IAS-2000 Page No.85 Slide No.89 Ans.(b) Rolling with smaller diagram rolls requires lower force.
IES-1993 Page No.86 Slide No.93 Ans.(a) In order to get uniform thickness of the plate by rolling process, one provides camber on the rolls to take care of unavoidable tool bending. Cylindrical rollers would result in production of plate with convex surface. Because of the limitations in the equipment and workability of the metal, rolling is accomplished progressively in many steps. Plate, sheet and strip are rolled between rolls having a smooth, cylindrical, slightly cambered (convex) or concave working surface.
IAS-2004 Page No.86 Slide No.95 Ans.(c) Rolling means hot rolling where no lubricant is used.
GATE -2009(PI) Page No.86 Slide No.98 Ans.(d) Due to directional granule deformation.
IES-2003 Page No.87 Slide No.100 Ans. (c) Wavy edges due to roller deflection.
GATE -2007 Page No.87 Slide No.105 Ans.(d)

h_o = 16 mm ; h_f = 10 mm ; D = 400 mm; R=200 mm $\therefore \Delta h = 6\,mm$;

$\Delta h = D(1-\cos\alpha)$

$6 = 400(1-\cos\alpha) \Rightarrow \alpha = 9.936°$

GATE – 2012 Same Q in GATE – 2012 (PI) Page No.87 Slide No.106 Ans.(c)

h_o = 8 mm ; h_f = 8 x $(1 - 0.1)$ = 7.2 mm; D = 410 mm;

$\Delta h = 10\%\ of\ 8\,mm = 0.8\,mm\ \left[alternative: h_o - h_f = 8 - 7.2 = 0.8\,mm\right]$

We know that, $\Delta h = D(1-\cos\alpha)\ or\ 0.8 = 410(1-\cos\alpha)$

$or\ \alpha = 3.58^o = 3.58 \times \frac{\pi}{180} rad = 0.062\,rad$

GATE -2017(PI) Page No.87 Slide No.107 Ans.(b)
GATE -1998 Page No.87 Slide No.108 Ans.(d) For strip rolling sheet rolling width remains same.
Initial thickness (h_1) = 4.5 mm.
As width constant therefore 20% reduction in area means 20% reduction in thickness also.
Final thickness (h_2 = 0.8 x 4.5 = 3.6 mm
$\Delta h = D(1-\cos\theta)$ or $(4.5-3.6) = 450(1-\cos\theta)$ or $\theta = 3.62° = 0.063$ radian

GATE -2018(PI) Page No.88 Slide No.109 Ans. *7.27 (7.1 to 7.4)*
GATE -2004 Page No.88 Slide No.111 Ans.(b)
Roll strip contact length, L = R α
$\Delta h = D(1-\cos\alpha)\ or\ (25-20) = 600(1-\cos\alpha)\ or\ \alpha = 7.402° = 0.129\,rad$
Therefore L = R α = 300 x 0.129 = 38.76 mm ≈ 39 mm

GATE -2011 Page No.88 Slide No.114 Ans.(a) Maximum possible draft. $\Delta h_{max} = \mu^2 R$
GATE -2014 Page No.88 Slide No.115 Ans.(b) Maximum possible draft. $\Delta h_{max} = \mu^2 R$
GATE -2018 Page No.88 Slide No.116 Ans. (b) Maximum possible draft. $\Delta h_{max} = \mu^2 R$
GATE -2016 Page No.88 Slide No.117 Ans. 1.92
$R = 300\,mm,\ and\ \Delta h_{max} = \mu^2 R = 0.08^2 \times 300 = 1.92\,mm$
GATE -2015 Page No.89 Slide No.118 Ans.0.1414
GATE -2015 Page No.89 Slide No.119 Ans. 5.71
IES-1999 Page No.89 Slide No.120 Ans.(b) Actually metal will get hardened in every pass due to strain hardening. Therefore in actual practice the reduction in second pass is less than in the first pass.
GATE-2006 Page No.89 Slide No.122 Ans.(c)

$(\Delta h)_{max} = h_o - h_{f,min} = \mu^2 R = 0.1^2 \times 150\,mm = 1.5\,mm$

$or\ 4 - h_{f,min} = 1.5\quad or\quad h_{f,min} = 2.5\,mm$

GATE – 2011 (PI) Page No.89 Slide No.124 Ans.(d)

$$(\Delta h)_{max} = \mu^2 R = (0.1)^2 \times 300\,mm = 3\,mm$$

Therefore we cannot reduce more than 3 mm in a single pass but we have to reduce total, 30 mm -10 mm = 20 mm

$$\therefore \text{Number of pass needed} = \frac{20}{3} \approx 7$$

IES-2001 Page No.89 Slide No.125 Ans.(a)

$R = 150\,mm; h_o = 30\,mm; h_f = 15\,mm$

$$\Delta h = \mu^2 R \quad or \quad \mu = \sqrt{\frac{\Delta h}{R}} = \sqrt{\frac{15}{150}} = \frac{1}{\sqrt{10}} \approx \frac{1}{3.something} \approx 0.3something$$

In IES objective exam calculators are not allowed, we have to use above apporx. calculation

GATE-2014(PI) Page No.89 Slide No.126 Ans.(b) same as above
GATE-1990(PI) Page No.90 Slide No.128 Ans.(b)
IES-2014 Page No.90 Slide No.129 Ans. (b)
GATE-2008(PI) Page No.90 Slide No.130 Ans.(a)

The velocity at neutral point is equal to the velocity of roller, as there is no slip occur

$$V = \frac{\pi DN}{60} = \frac{\pi \times 0.300m \times 100rpm}{60} = 1.57\,m/s$$

IES-2002 Page No.90 Slide No.131 Ans.(d)
Selected Questions Page No.90 Slide No.132 Ans.(c & d)
GATE-2014 Page No.90 Slide No.134 Ans.14.6 to 14.8 m/min

The inlet and outlet volume rates of material flow must be the same, that is,

$$h_o b_o v_o = h_f b_f v_f$$

$$h_f = \frac{2}{3} h_o; b_f = 1.02 b_o; v_o = 10m/\min$$

$$h_o b_o \times 10 = \frac{2}{3} h_o \times 1.02 b_o v_f \Rightarrow v_f = 14.706\,m/\min$$

GATE-1992(PI) Page No.91 Slide No.136 Ans.(d)

$$\text{Elongation factor} = E = \frac{A_o}{A_1} = 1.22 ....(given)$$

$$E^n = \frac{A_o}{A_n} \quad or\ 1.22^n = \frac{750 \times 750}{250 \times 250} \quad or\ 11.04$$

GATE-2016(PI) Page No.91 Slide No.139 Ans. 2000 (Range 1990 to 2010)

$$F = \sigma_o L_p b = \sigma_o \times \sqrt{R\Delta h} \times b$$

$$= 500 \times \sqrt{100 \times 4} \times 200\,N = 2000\,KN$$

GATE-2008 Page No.91 Slide No.140 Ans.(a)

$\Delta h = 20\,mm - 18\,mm = 2\,mm = 0.002\,m$

$R = 250\,mm = 0.250\,m$

$\text{Projected Length}(L_p) = \sqrt{R\Delta h} = \sqrt{0.250 \times 0.002} = 0.02236\,m$

$\text{Arm length}(a) = \lambda\sqrt{R\Delta h} = 0.5\sqrt{0.250 \times 0.002} = 0.01118\,m$

$\text{Force}(F) = \text{Pressure} \times \text{Projected area} = \sigma_o \times (L_p \times b) = (300 \times 10^6) \times 0.02236 \times 0.1 = 670.8\,kN$

$\text{Torque}(T) = F \times a$ [Force F on both roller]

$= (670.8 \times 10^3) \times 0.01118 = 7.5\,kNm$

$$\text{Total Power for both roller}(P) = 2 \times T \times \omega = 2 \times T \times \frac{2\pi N}{60} = 2 \times (7.5 \times 10^3) \times \frac{2\pi \times 10}{60} = 15.7\,KW$$

GATE-2017 Page No.91 Slide No.141 Ans.

This question is wrong. For proper calculation we need velocity of neutral plane or velocity of roller. But in this question velocity of exit is given. From velocity of exit we may assume the velocity of neutral plane but can't calculate correctly.

$\text{Projected length}\ (L_p) = R\sin\alpha \approx \sqrt{R\Delta h},\ mm = \sqrt{150 \times (8 - 7.2)} = 10.954\,mm$

$\text{Projected Area}\ (A_p) = L_p \times b,\ mm^2 = 10.954 \times 120 = 1314.48\,mm^2$

$\text{Roll Separating Force}\ (F) = \sigma_o \times L_p \times b\ ,\ N = 200 \times 1314.48\,N = 262.9\,KN$

$[\sigma_o\ in\ N/mm^2\ i.e. MPa]$

$\text{Arm length}\ (a\ in\ mm) = 0.5 L_p$ for hot rolling $= 0.5 \times 10.954\,mm = 5.477\,mm$

$= 0.45 L_p$ for cold rolling

$$\text{Torque per roller}\ (T) = F \times \frac{a}{1000}\ ,\ Nm = 262.9\,KN \times 5.477\,mm = 1439.9\,Nm$$

$$\text{Total power for two roller}\ (P) = 2T\omega\ ,\ in\ W = 2T \times \frac{2\pi N}{60}$$

Assuming velocity of neutral plane = velocity at exit (V) = $30\,m/\min = 0.5\,m/s$

$$\omega = \frac{V}{R} = \frac{0.5\,m/s}{0.150\,m} = 3.3333\,rad/s$$

$\therefore$ Total power for two roller (P)

$$= 2T \times \omega = 2 \times 1439.9 \times 3.3333,\ W = 9.6\,kW$$

IAS-2017 Main. Page No.91 Slide No.142

$$F = \sigma_0 \sqrt{R\Delta h} \times b = 400\sqrt{400 \times 4} \times 300 = 4.8\,MN$$

IES – 2000, GATE-2010(PI) Page No.91 Slide No.143 Ans.(a) The roll-separating force which separates the two rolls apart can be obtained by multiplying the average roll pressure with the total contact area. The average roll pressure can be decreased by reducing the maximum pressure, which is a function of the contact length. Smaller contact lengths means lesser friction forces acting. Thus, by reducing the contact length, it is possible to decrease the roll-separating force. This in turn, can be achieved by reducing the roll diameter, since; smaller rolls would have less contact length than larger rolls for the same reduction.

IAS-2007 Page No.91 Slide No.144 Ans.(c) Use small dia rolls to reduce Roll force.

IES-2001 Page No.92 Slide No.146 Ans.(a) Coefficient of friction is constant over the arc of contact and But does not acts in one direction throughout the arc of contact.

IFS-2010 Page No.92 Slide No.149 Ans. Rolling analysis needed. Not needed for mechanical GATE and IES Prelims. Only for IES Conventional.

IAS-1998 Page No.92 Slide No.150 Ans.(d)

Ch-9 Forging: Answers with Explanations

IES-2013 Page No.93 Slide No. 155 Ans.(a)
IES-1996 Page No.93 Slide No. 159 Ans.(d)

IES-2013 Page No.93 Slide No. 160 Ans.(c) Forging components poses high reliability i.e. point3. is wrong, means (a), (b) and (d) wrong.

IES-2005 Page No.93 Slide No. 161 Ans.(b)

IES-2012 Page No.93 Slide No. 162 Ans.(b) If undercut is present it is not moldable means can't be withdrawn from die.

IES-2016 Page No.94 Slide No. 163 Ans.(a)

- Forging means hot working it will increases strength and ductility both.
- Hot working reduced or eliminates porosity of the metal and increase resistance toshock and vibrating.
- Forging pressure is not uniform so it can't guarantee uniformly and forging has poordimensional accuracy and surface finish.

ISRO-2013 Page No.94 Slide No. 164 Ans.(b)
IES-2012 Page No.94 Slide No. 166 Ans.(c)

IES-2006 **Page No.94** **Slide No. 168** **Ans.(c)** The draft provided on the sides for withdrawal of the forging.
IES-2014 **Page No.94** **Slide No.171** **Ans. (b)**
IES-2016 **Page No.95** **Slide No.172** **Ans. (a)**
IAS-2002 **Page No.95** **Slide No. 173** **Ans.(b)**Amount of flash depends on the forging size not on forging force.
IES – 1993, GATE-1994(PI) **Page No.95** **Slide No.176** **Ans.(a)**Closed die forging requires the provision of gutters to provide space for excess material and ensure complete closure of die and defect free forged part.
IES-1997 **Page No.95** **Slide No.177** **Ans.(c)** The provision of gutters to provide space for excess material and ensure complete closure of die and defect free forged part.
GATE-1989(PI) **Page No.95** **Slide No. 178** **Ans.** Gutter
IES-2015 **Page No.95** **Slide No. 179** **Ans.(c)**
IES-1998 **Page No.96** **Slide No. 182** **Ans.(c)**
IES-2001 **Page No.96** **Slide No. 183** **Ans.(a)**
IES-2003 **Page No.96** **Slide No. 184** **Ans.(a)**
IES-2011 **Page No.96** **Slide No. 185** **Ans.(a)**
IES-2005 **Page No.96** **Slide No. 186** **Ans.(c)**
IES-2002 **Page No.96** **Slide No. 187** **Ans.(b)**
IES-2003 **Page No.96** **Slide No. 188** **Ans.(d)**
IAS-2001 **Page No.96** **Slide No. 189** **Ans.(b)**
IES-2012 Conventional **Page No.97** **Slide No. 190** **Ans. refer theory slides**
IAS-2003 **Page No.97** **Slide No. 191** **Ans.(a)** The term swaging is also applied to processes where material is forced into a confining die to reduce its diameter.
IES – 1994, ISRO-2010 **Page No.97** **Slide No. 194** **Ans.(c)**The drop forging die consists of two halves. The lower half of the die is fixed to the anvil of the machine, while the upper half is fixed to the ram. The heated stock is kept in the lower die while the ram delivers four to five blows on the metal, in quick succession so that the metal spreads and completely fills the die cavity. When the two die halves close, the complete cavity is formed.
IAS-2000 **Page No.97** **Slide No. 195** **Ans.(a)** Due to low toughness.
IES-2011 **Page No.97** **Slide No. 198** **Ans.(b)**
IES-2005 **Page No.98** **Slide No. 206** **Ans.(c)**
IES-2008 **Page No.98** **Slide No. 207** **Ans.(a)**
IES-2013 **Page No.99** **Slide No. 209** **Ans.(a)**As K.E $\propto V^2$, high energy is delivered to the metal with relatively small weights (ram and die).
IES-2008 **Page No.99** **Slide No. 213** **Ans.(None)** Correct sequence is 2 – 1 – 3 - 4
IAS-1998 **Page No.100** **Slide No. 218** **Ans.(b)**
IES-2011 **Page No.100** **Slide No. 219** **Ans.(c)** Bonding between the inclusions and the parent material is through physical bonding no chemical bonding possible.
GATE-2008(PI) **Page No.100** **Slide No. 220** **Ans.(c)**
IES-2013 **Page No.100** **Slide No. 223** **Ans.(b)**
GATE-2010(PI) **Page No.100** **Slide No. 225** **Ans.(c)**Low thermal conductivity because low heat loss from workpiece.
IES-2013 **Page No.101** **Slide No. 228** **Ans.(b)**
GATE-2014 **Page No.101** **Slide No. 230** **Ans.(c)**

$$\text{Engineering strain or Conventional Strain}(\varepsilon_E) = \frac{\text{elongation}}{\text{original length}}$$

$$\text{True Strain}(\varepsilon_T) = \frac{\text{elongation}}{\text{instantaneous length}}$$

If suppose x is the length; dx is the elongation which is infinitely small

$$\varepsilon_T = \int_{L_o}^{L} \frac{dx}{x} = \ln\frac{L}{L_o}$$

$$as\ \frac{L}{L_o} = \frac{L_o + \Delta L}{L_o} = 1 + \frac{\Delta L}{L_o} = 1 + \varepsilon_E$$

$$\varepsilon_T = \ln(1+\varepsilon_E)$$

$\because$ volume change will not be there so, $A_o L_o = AL$

$$\frac{L}{L_o} = \frac{A_o}{A} = \frac{(\pi/4)d_o^2}{(\pi/4)d^2}$$

$$\ln\frac{L}{L_o} = \ln\frac{A_o}{A} = 2\ln\frac{d_o}{d}$$

GATE-1992, ISRO-2012, VS-2013 **Page No.101** **Slide No. 231** **Ans.(c)**

$$\varepsilon_T = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{2L_0}{L_o}\right) = \ln 2 = 0.693$$

GATE-2016 **Page No.101** **Slide No. 232** **Ans.(c)**

$$\varepsilon_T = \ln(1+\varepsilon) = \ln\left(1+\frac{0.100}{100}\right)\times 100\% = 0.09995$$

GATE-2007 **Page No.101** **Slide No. 233** **Ans.(c)**

$$\text{True strain}(\in_T) = \int_{L_o}^{L}\frac{dx}{x} = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{A_o}{A}\right) = 2\ln\left(\frac{D_o}{D}\right) = 2\ln\left(\frac{200}{400}\right) = -1.386$$

negativesign indicates compressive strain.

GATE-2017(PI) **Page No.101** **Slide No. 234** **Ans. 1.833 Range (1.80 to 1.85)**

GATE-2016 **Page No. 101** **Slide No. 235** **Ans.(b)**

$$\varepsilon_T = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{L_o/2}{L_o}\right) = -\ln 2 = -0.69$$

GATE-2018 **Page No. 102** **Slide No. 236** **Ans.** *0.693*

Initial length = L_0

Final length $(L) = \frac{L_0}{2}$

$$\text{True strain} = \varepsilon_T = \ln\frac{L}{L_o} = \ln\left[\frac{\left(\frac{L_0}{2}\right)}{L_0}\right] = -0.693$$

As examiner mentioned "magnitude" only magnitude will be given 0.693

GATE-2017 **Page No.102** **Slide No. 237** **Ans.(b)**
For calculating true strain we have to know initial and final length only.

$$Initial\ length(L_o) = 20\,mm$$

$$Final\,length\,(L) = 10\,mm$$

$$True\,strain\,(\varepsilon_T) = \ln(1+\varepsilon) = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{A_o}{A}\right) = 2\ln\left(\frac{d_o}{d}\right)$$

$$True\,strain\,(\varepsilon_T) = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{10}{20}\right) = -0.693$$

GATE-2018 Page No. 102 Slide No. 239 Ans. . *(67.032)*

Given, $\sigma = 1020 \times \varepsilon^{0.4}$

at UTS, ε_T = n = 0.4

at UTS, neak formation starts, Let, A_f is cross-section area at the time of necking,

$$\varepsilon_T = 0.4 = \ln\left(\frac{A_0}{A_f}\right) = \ln\left(\frac{100}{A_f}\right)$$

$$or \quad A_f = 67.032\ mm^2$$

GATE-2006 Page No.102 Slide No. 242 Ans.(b)

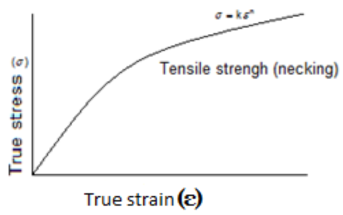
$\epsilon_T = \ln(1 + \epsilon_o) = \ln(1 + 0.35) = 0.3$

But at UTS $n = \epsilon_T$

$\sigma_f = \sigma_o(1 + 0.3) = 400(1 + 0.35) = 540\ MPa$

$\sigma_f = K\ \epsilon_T^n$

$540 = K(0.3)^{0.3}$



GATE-2015 Page No.102 Slide No. 243 Ans.(c)
GATE-2017 Page No.103 Slide No. 244 Ans.(b)
GATE-2012 Same Q GATE -2012 (PI) Page No.103 Slide No. 245 Ans.(d)

Volume of material will remain same due to incompressibility

$$\frac{\pi d_1^2}{4} \times h_1 = \frac{\pi d_2^2}{4} \times h_2$$

$$d_2 = d_1\sqrt{\frac{h_1}{h_2}} = 100 \times \sqrt{\frac{50}{25}} = 141.42\,mm$$

$$\text{Percentage change in diameter} = \frac{d_2 - d_1}{d_1} \times 100\% = 41.42\%$$

GATE-2016(PI) Page No.103 Slide No. 246 Ans. 1.0 (Range 1.0 to 1.0)
GATE-2015 Page No.103 Slide No.247 Ans. 95.19 mm

$$\text{True strain} = \ln\frac{100}{95} = 0.5129$$

$$\sigma = 500 \times (0.5129)^{0.1} = 371.51$$

Upto elastic limits using Hooke's Law

$$E = \frac{\sigma \times l}{\Delta l}\ or\ 200 \times 10^9 = \frac{371.51 \times 10^6 \times 100}{\Delta l}$$

$\Delta l = 0.18575\,mm$ (considering this for elastic recovery)

This is elastic component and after release of the compressive load this amount of recovery takes place.

This will be added to 95mm. Therefore, final dimension = 95.18575mm

GATE-2018 Page No.103 Slide No.248 Ans.

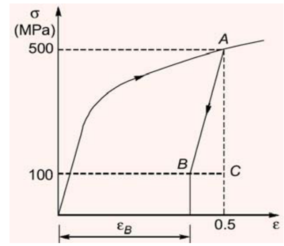
We know that, Slope of AB line is E

$$E = \frac{AC}{BC}$$

$$200 \times 10^3\ \text{MPa} = \frac{(500 - 100)\,MPa}{BC}$$

$$BC = \frac{400}{200 \times 10^3} = 0.002$$

$\varepsilon_B = 0.5 - 0.002 = 0.498$



GATE-2000(PI) Page No.103 Slide No.249 Ans. 7068 J , 0.6968 m

$$\frac{\pi d_o^2}{4} \times h_o = \frac{\pi d_f^2}{4} \times h_f$$

$$or \quad \frac{\pi \times 100^2 \times 50}{4} = \frac{\pi \times d_f^2 \times 40}{4} \quad or\ d_f = 111.8\,mm$$

$$\text{Initial Force}(P_o) = \frac{\pi d_o^2}{4} \times \sigma_o = \frac{\pi \times 100^2}{4} \times 80 = 628.3\,KN$$

$$\text{Final Force}(P_f) = \frac{\pi d_f^2}{4} \times \sigma_o = \frac{\pi \times 111.8^2}{4} \times 80 = 785.35\,KN$$

$$\text{Average Force}(P_{avg}) = \frac{P_o + P_f}{2} = \frac{628.3 + 785.35}{2} = 706.8\,KN$$

$$\text{Workdone}(W) = P_{avg} \times (h_o - h_f) = 706.8 \times (50 - 40)J = 7068\,J$$

$$mg(h + x) = W \quad [x = h_o - h_f]$$

$$10 \times 10^3 (h + 0.010) = 7068 \quad or\ h = 0.6968\,m$$

GATE-2000(PI) Page No.103 Slide No.251 Ans. (c)

Ch-10 Extrusion and Drawing: Answers with Explanations

IES-2007 Page No.104 Slide No. 256 Ans. (d)

The equipment consists of a cylinder or container into which the heated metal billet is loaded.
On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, and acquiring the shape of the opening. The extruded metal is then carried by the metal-handling system as it comes out of the die.

DRDO-2008 Page No.104 Slide No. 258 Ans.(b)
IES-2012 Page No.104 Slide No. 260 Ans.(c)
Advantages: 1. Material saving 2. Process time saving 3. Saving in tooling cost
All are correct but only a die change can change the product therefore (c) is most appropriate.
IES-2009 Page No.104 Slide No. 261 Ans.(c)
IES-1994 Page No.105 Slide No. 264 Ans.(c) Metal extrusion process is generally used for producing constant solid and hollow sections over any length.
GATE-1994 Page No.105 Slide No. 265 Ans. (a)
IES-1999 Page No.105 Slide No. 267 Ans.(c)
IES-2009 Page No.105 Slide No. 270 Ans. (b)
IES-1993 Page No.106 Slide No. 272 Ans. (b) ***Both*** A and R are true but R is not correct explanation of A. Zinc phosphate coating is used to prevent metal contact.In direct extrusion, friction with the chamber opposes forward motion of the billet. For indirect extrusion, there is no friction, since there is no relative motion.
IES-2000 Page No.106 Slide No.273 Ans.(c) As diameter decreases therefore for same mass flow rate the speed of travel of the extruded product must be greater than that of the ram.
IES-2012 Page No.106 Slide No. 276 Ans.(c) The force required on the punch is less in comparison to direct extrusion.
IES-2007 Page No.106 Slide No. 277 Ans. (b) In direct extrusion, friction with the chamber opposes forward motion of the billet.
IAS-2004 Page No.106 Slide No. 278 Ans. (d) Only ram movement is there.
IES-2016 Page No.106 Slide No. 279 Ans. (a) In the direct extrusion a significant amount of energy is used to overcome frictional resistance between workpiece and cylinder wall.
IES – 2008, GATE-1989(PI) Page No.107 Slide No.283 Ans. (a) Impact Extrusion is used for manufacture of collapsible toothpaste tubes
IES-2003 Page No.107 Slide No. 284 Ans. (d)
IES-2014 Page No.107 Slide No.285 Ans. (c)
IAS-2000 Page No.108 Slide No. 293 Ans. (d) Hydrostatic extrusion suppresses crack formation by pressure induced ductility. Relative brittle materials can be plastically deformed without fracture. And materials with limited ductility become highly plastic.
IES-2006 Page No.108 Slide No.294 Ans. (a) It is pressure induced ductility.
GATE-1990(PI) Page No.108 Slide No. 295 Ans.(c)
IES-2001 Page No.108 Slide No.296 Ans. (d)
IES-2009(conventional) Page No. 109 Slide No. 298 Ans.
For sketches refer slides.
(i)Direct Extrusion-curtain rods
(ii) Indirect Extrusion-
(iii) Hydrostatic Extrusion-Cladding of metals, Extrusion of nuclear fuel reactor fuel rod
(iv) Impact Extrusion-Collapsible tubes for toothpastes, creams etc.
IES-2014 Page No.109 Slide No.300 Ans. (d) For high extrusion pressure, the initial temperature of billet should be low.
IES-2018(PI) Page No.109 Slide No.302 Ans. (d)
IES-2016 Page No.109 Slide No.3030 Ans. (b) Bamboo defects at low temperature due to sticking of metals in die land.
JWM-2010 Page No.109 Slide No. 304 Ans. (a)
GATE-2014 Page No.109 Slide No. 306 Ans. (b)
IES-2007 Page No.110 Slide No. 310 Ans.(c)
IES-2009 Page No.110 Slide No. 311 Ans. (b) The wire is subjected to tension only. But when it is in contact with dies then a combination of tensile, compressive and shear stresses will be there in that portion only.
IES-2005 Page No.110 Slide No. 312 Ans. (a)
GATE-1987 Page No.110 Slide No. 313 Ans. (a)
IES-2016 Page No.110 Slide No. 314 Ans.(c)
IES-2010 Page No.111 Slide No. 316 Ans.(c)
Cleaning is done to remove scale and rust by **acid pickling.**
Lubrication boxes precede the individual dies to help reduce friction drag and prevent wear of the dies. It is done by **sulling, phosphating, electroplating.**

IES-2000 Page No.111 Slide No.317 Ans.(c)
IAS-1995 Page No.111 Slide No. 318 Ans. (d) The correct sequence for preparing a billet for extrusion process is pickling, alkaline cleaning, phosphate coating, and lubricating with reactive soap.
IES-1996 Page No.111 Slide No. 319 Ans. (d)
IES-2014 Page No. 111 Slide No. 321 Ans. (b)
IES-1993; GATE-1994(PI), 2014(PI) Page No. 112 Slide No. 326 Ans. (b)
IAS-2006 Page No.112 Slide No. 327 Ans. (b)
IES-2015 Page No.112 Slide No. 330 Ans. (a)
IES-1993 Page No.112 Slide No. 331 Ans. (a) Tandem drawing of wires and tubes is necessary because it is not possible to reduce at one stage.
IES-2000 Page No.112 Slide No. 332 Ans. (d)
IES-1999 Page No.112 Slide No. 333 Ans. (d)
IES-1996 Page No.113 Slide No. 334 Ans.(c)
IES-1994 Page No.113 Slide No. 335 Ans. (d)
IES-1993, ISRO-2010, Page No. 113 Slide No. 336 Ans. (b)since malleability is related to cold rolling, hardness to indentation, resilience to impact loads, and isotropy to direction**.**
IES-2002 Page No.113 Slide No. 337 Ans. (a)
IAS-2001 Page No.113 Slide No. 338 Ans. (a)
GATE-2015 Page No.113 Slide No. 339 Ans. (b)
IAS-2002 Page No.113 Slide No. 340 Ans. (b)
IES-2011 Page No.113 Slide No. 341 Ans. (b)
GATE-2018 Page No.113 Slide No. 342 Ans. (c)
IAS-1994 Page No.114 Slide No.345 Ans. (b) Extrusion and skew rolling produce seamless metallic tubes.
GATE-2003 Page No.114 Slide No. 350 Ans. (b)
Extrusion constant $(k) = 250\text{MPa}$

Initial area $(A_o) = \dfrac{\pi d_o^2}{4}$ and Final area $(A_f) = \dfrac{\pi d_f^2}{4}$

Force required for extrusion:

$$P = kA_0 \ln\left(\frac{A_o}{A_f}\right) = 250\times\frac{\pi}{4}\times 0.1^2 \ln\left(\frac{\pi/4\times 0.1^2}{\pi/4\times 0.05^2}\right) = 2.72219 MN$$

GATE-2009(PI) Page No.114 Slide No.351 Ans. (a)

$$\text{Pressure}(\sigma) = \sigma_o \ln\left(\frac{A_o}{A_f}\right) = \sigma_o \ln r = 300\ln 4 = 416\,MPa$$

GATE-2006 Page No.115 Slide No. 352 Ans. (b)
Given : $D_o = 10\,\text{mm}; D_f = 8\,\text{mm}; \sigma_0 = 400\,\text{MPa}$; Ignore friction and redundant work means

$$\text{Ideal Force} = 2\sigma_0 A_f \ln\left(\frac{r_o}{r_f}\right) = 2\times 400\times\frac{\pi\times 8^2}{4}\ln\left(\frac{5}{4}\right) = 8.97\,\text{kN}$$

GATE -2008 (PI) Linked S-1 Page No. 115 Slide No.353 Ans. (b)
$d_o = 10\,mm,\ d_f = (1-0.2)\times d_o = (1-0.2)\times 10 = 8\,mm$

$$Stress(\sigma_d) = \sigma_o \ln\left(\frac{A_o}{A_f}\right) = 2\times\sigma_o\times\ln\left(\frac{d_o}{d_f}\right) = 2\times 800\times\ln\left(\frac{10}{8}\right) = 357\,MPa$$

GATE -2008 (PI) Linked S-2 Page No.115 Slide No. 354 Ans. (a)

$$Power = Drawing\ force\times Velocity$$
$$= Stress(\sigma_d)\times area(A_f)\times Velocity$$
$$= 357\times\frac{\pi\times 8^2}{4}\times 0.5W = 8.97\,KW$$

IES-2014 Conv. Page No.115Slide No. 355 Ans. 190 N
GATE-2001, GATE -2007 (PI) Page No.115 Slide No. 356 Ans. (b)

$$\sigma_d = \sigma_o \ln\left(\frac{A_o}{A_f}\right) \text{ For Maximum reduction}, \sigma_d = \sigma_o$$

$$\sigma_o = \sigma_o \ln\left(\frac{A_o}{A_f}\right) \text{ or } \frac{A_o}{A_f} = e = 2.71828 \therefore \frac{A_o - A_f}{A_o}\times 100 = \left(1-\frac{1}{e}\right)\times 100 = 63\%$$

GATE-2018 Page No.115 Slide No. 357 Ans. (d)
IES-2014 Page No.115 Slide No.358 Ans. (b)
GATE-1996 Page No.115 Slide No. 359 Ans. (b)

$Case(a): 3-stage$ reduction final dia $=15\times(1-0.8)\times(1-0.8)\times(1-0.8) = 0.12\,mm \therefore error = 0.02mm$

$(b)\,4-stage$ reduction final dia $=15\times(1-0.8)\times(1-0.8)\times(1-0.8)\times(1-0.2) = 0.096mm \therefore error = 0.004mm$

$(c)\,5-stage$ reduction final dia

$=15\times(1-0.8)\times(1-0.8)\times(1-0.4)\times(1-0.4)\times(1-0.2) = 0.1728mm \therefore error = 0.0728mm$

GATE-2015 Page No.115 Slide No. 360 Ans. (b)
GATE-2018(PI) Page No.116 Slide No. 361 Ans. 58
IES-2011(conventional) Page No. 116 Slide No.364 Ans.

$d_o = 12.5mm; d_f = 10mm; V = 100m/\min; \alpha = 5°; \mu = 0.15; \sigma_o = 400MPa$

$B = \mu\cot\alpha = 0.15\cot 5 = 1.7145$

$$\sigma_d = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_f}{r_o}\right)^{2B}\right]$$

$$\sigma_d = \frac{400(1+1.7145)}{1.7145}\left[1-\left(\frac{5}{6.25}\right)^{2\times1.7145}\right] = 338.653MPa$$

$$Force(P) = 338.653\times\frac{\pi}{4}10^2\,N$$

$$Power = P\times V = 338.653\times\frac{\pi}{4}10^2\times\frac{100}{60}m/s = 44.329kW$$

Maximum possible reduction; $\sigma_o = \sigma_d$

$$\sigma_o = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_{f\min}}{r_o}\right)^{2B}\right] \;or\; 400 = \frac{400(1+1.7145)}{1.7145}\left[1-\left(\frac{r_{f\min}}{r_o}\right)^{2\times1.7145}\right] or\; r_{f\min} = 4.67mm$$

$$\text{Max possible reduction in dia} = \frac{d_o - d_{f\min}}{d_o}\times100\% = \frac{r_o - r_{f\min}}{r_o}\times100\% = 25.3\%$$

If the rod is subjected to a back pressure of 50 N/mm²

$$\sigma_d = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_f}{r_o}\right)^{2B}\right]+\left(\frac{r_f}{r_o}\right)^{2B}.\sigma_b$$

$$\sigma_d = \frac{400(1+1.7145)}{1.7145}\left[1-\left(\frac{5}{6.25}\right)^{2\times1.7145}\right]+\left(\frac{5}{6.25}\right)^{2\times1.7145}\times50 = 361.26MPa$$

For maximum possible reduction; $\sigma_o = \sigma_d$

$$\sigma_o = \frac{\sigma_o(1+B)}{B}\left[1-\left(\frac{r_{f\min}}{r_o}\right)^{2B}\right]+\left(\frac{r_{f\min}}{r_o}\right)^{2B}.\sigma_b$$

$$400 = \frac{400(1+1.7145)}{1.7145}\left[1-\left(\frac{r_{f\min}}{6.25}\right)^{2\times1.7145}\right]+\left(\frac{r_{f\min}}{6.25}\right)^{2\times1.7145}\times50 \Rightarrow r_{f\min} = 4.78mm$$

$$\text{Max possible \% reduction in diameter} = \frac{d_o - d_{f\min}}{d_o}\times100\% = 23.5\%$$

$$\text{Max possible \% reduction in area} = \frac{A_o - A_{f\min}}{A_o}\times100\% = 41.5\%$$

GATE – 2018 Page No. 116 Slide No. 365 Ans. *(316.25)*

$d_i = 10\,mm,\; d_f = 7.5\,mm,\; \alpha = 5°,\; \mu = 0.1,\; [\sigma_y]_{avg} = 350\; MPa$

$$\sigma_f = (\sigma_y)_{avg}\left\{1+\frac{1}{\mu\cot\alpha}\right\}\left[1-\left(\frac{d_f}{d_i}\right)^{2\mu\cot\alpha}\right]$$

$$\sigma_f = 350\times\left\{1+\frac{1}{0.1\times\cot5°}\right\}\left[1-\left(\frac{7.5}{10}\right)^{2\times0.1\times\cot5°}\right] \simeq 316.25\,MPa$$

IFS-2016 Page No. 116 Slide No. 366 Ans (i) 5.594 KW and (ii) 73.24 MPa

GATE – 2011 (PI) Common Data-S1 Page No. 116 Slide No. 367 Ans.(c)

$$\text{Initial area}(A_o) = \frac{\pi d_o^2}{4} = \frac{\pi\times10^2}{4}mm^2 = 78.54\,mm^2$$

$$\text{After first pass area}(A_1) = (1-0.35)\,A_o = (1-0.35)\times78.54\,mm^2 = 51\,mm^2$$

$$\text{After second pass area}(A_2) = (1-0.35)^2\,A_o \;and\; then........$$

$$\text{After } 7^{th} \text{ pass area}(A_7) = (1-0.35)^7\,A_o = (1-0.35)^7\times78.54\,mm^2 = 3.85\,mm^2$$

$$True\;strain = \ln\left(\frac{L}{L_o}\right) = \ln\left(\frac{A_o}{A}\right) = \ln\left(\frac{78.54}{3.85}\right) = 3.02$$

$$and\;\; A_oL_o = A_7L_7 \;or\; 78.54\times100 = 3.85\times L_7 \;\Rightarrow L_7 = 2040\,mm$$

GATE – 2011 (PI) Common Data-S-2 Page No. 116 Slide No. 368 Ans. (d)

$$P = \sigma_oA_f\ln\left(\frac{A_o}{A_f}\right) = \sigma_oA_1\ln\left(\frac{A_o}{A_1}\right) = 200\times51\times\ln\left(\frac{78.54}{51}\right)N = 4.40\,KN$$

GATE-2014 Page No.116 Slide No. 369 Ans. = 0.9 to 1.1

True strain at any instant t $(\varepsilon_T) = \int \frac{dL}{L} = \int \frac{dL}{L_0(1+t^2)} = \int_0^t \frac{2tdt}{(1+t^2)} = \ln[1+t^2]$

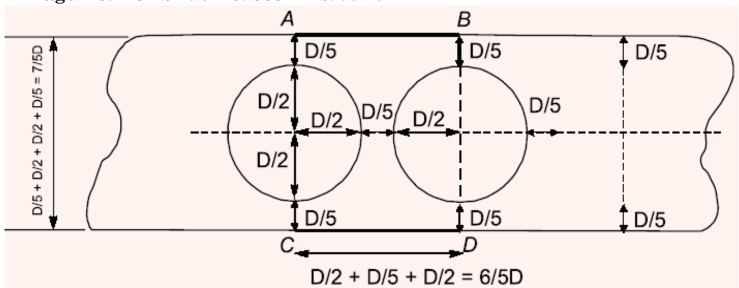
$as, L = L_0(1+t^2), \therefore dL = L_0 2tdt$

$\dot{\varepsilon}_T = \frac{d\varepsilon_T}{dt} = \frac{2t}{(1+t^2)} = \frac{2\times 1}{1+1^2} = 1.0$

IAS-1997 **Page No.117 Slide No. 370 Ans.(c)**
IES-2012 **Page No.117 Slide No. 371 Ans. Refer slides**
IAS-2006 **Page No.117 Slide No. 373 Ans. (c)**

Ch-11 Sheet Metal Operation: Answers with Explanations

GATE-2018 **Page No.118 Slide No. 383 Ans.** *53.25*



This rectangle ABCD will be repeated again and again.

A_t = Total Area $= \frac{7}{5}D \times \frac{6}{5}D = \frac{42}{25}D^2$

A_u = Area of blanking Disc $= \frac{\pi D^2}{4}$

% of scrap $= \frac{A_t - A_u}{A_t} \times 100\% = \left[1 - \frac{\left(\frac{\pi}{4}\right)}{\frac{42}{25}}\right] \times 100\% = 53.25\%$

Example **Page No.119 Slide No. 389 Ans.**

The clearance to be provided is given by, C = 0.0032 × t × √τ
Shear strength of annealed C20 steel = 294 MPa
Hence, C = 0.0032 ×1.5 × 294 = 0.0823 mm
Since it is a blanking operation,
Die size = blank size = 20 mm
Punch size = blank size – 2 C = 20 – 2 × 0.0823 = 19.83 mm
Now when it is punching operation,
Punch size= size of hole = 20 mm
Die size = Punch size +2 C = 20 +2 × 0.0823 = 20.1646 mm

GATE-2003 **Page No.119 Slide No.390 Ans.(a)**

It is blanking operation
Therefore Diameter of die = metal disc diameter = 20 mm
3% clearance (c) = 0.06 mm on both side of the die (of sheet thickness)
Therefore Diameter of punch = 20 – 2c = 20 – 2 x 0.06 = 19.88 mm

Example **Page No.119 Slide No. 393 Ans.**

Solution: (a) Perimeter of blank = 2 (25 + 30)
=110 mm

∴ Blanking force = Area under shear × ultimate shear stress
= Perimeter × t × τ_s
= 110 × 1.5 × 450
= 74.25 kN

(b) Punch travel = Percentage penetration
$= \frac{1}{4} \times t = \frac{1.5}{4} = 0.375$ mm

Work done = Force × punch travel
$= 74.25 \times 10^3 \times 0.375 \times \frac{1}{10^3}$
= 27.84 Nm

GATE-2014 **Page No.119 Slide No. 394 Ans.(b)**

Punching Force(F) $= Lt\tau$

$F = 2(a+b)t\tau = 2(100+50)\times 5 \times 300 = 450\,kN$

IAS-2011(main) **Page No.119 Slide No. 395 Ans.**

For punching operation 10 mm circular hole

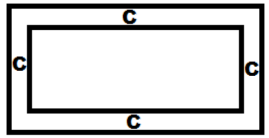
$d = 10\,mm; t = 1\,mm; \tau = 240\,MPa$

(i) Punch size = size of hole = 10 mm

(ii) Die size = Punch size + 2 C = 10 $+ 2(0.0032 t\sqrt{\tau})$=10 $+ 2(0.0032\times 1\times\sqrt{240})$= 10.09914 mm

(iii) Punching Force(F) $= Lt\tau = \pi dt\tau = \pi \times 10 \times 1 \times 240N = 7.54\,KN$

For blanking 50×200 mm rectangular blank



(i) Punch size = size -2C

Length will be= 200-2C=200 - $2(0.0032\times 1\times\sqrt{240})$ =199.90 mm

Width will be = 50 -2C =50 - $2(0.0032\times 1\times\sqrt{240})$ = 49.90 mm

(ii) Die size = correct size

Length will be= 200 mm

Width will be = 50 mm

$(iii)\, F = 2(a+b)t\tau = 2(200+50)\times 1\times 240 = 120\,kN$

GATE-2016(PI) Page No.119 Slide No. 396 **Ans. 0.25** (Range 0.24 to 0.26)

IES-1999 **Page No.120 Slide No.398 Ans.(b)** min dia $=4t\frac{f_s}{f_c} = 4\times 20 \times \frac{3}{6} = 30\,mm$

IES-2014 **Page No.120 Slide No.399 Ans. (c)**

ISRO-2008, 2011 Page No.120 Slide No. 400 **Ans.(c)** $\pi dt\tau \le \sigma_c \times \frac{\pi d^2}{4} \quad or\; d \ge \frac{4t\tau}{\sigma_c} = \frac{4t\tau}{4\tau} = t$

IES-2013 **Page No.120 Slide No. 401 Ans.(c)same as previous question**
EXAMPLE **Page No.121 Slide No. 406 Ans.**

Maximum force without shear = 550 x 100 x π x 5.6 N = 968 kN
Capacity of press, F = 30 T = 30 x 9.81 KN = 294 KN

$F = \frac{F_{max} \times pt}{s + pt} \quad or\; 294 = \frac{968 \times 0.4 \times 5.6}{s + 0.4 \times 5.6} \quad or\; s = 5.13\,mm$

Angle of shear, tanθ = 5.13/100 or θ = 2.9°

EXAMPLE **Page No.121 Slide No. 407 Ans.**

$d_1 = 25.4\,mm; d_2 = 12.7\,mm; t = 1.5\,mm; \tau = 280 N/mm^2$

Total cutting force when both punches act at the same time and no shear is applied to either the die or punch;

$F = \pi d_1 t\tau + \pi d_2 t\tau = \pi \times 25.4 \times 1.5 \times 280 + \pi \times 12.7 \times 1.5 \times 280 = 50.27 KN$

The cutting force if the punches are staggered, so that only one punch acts at a time:

$F_{max} = \pi d_{outside} t\tau = \pi \times 25.4 \times 1.5 \times 280 = 33.515\,kN$

Taking 60% penetration and shear on punch of 1 mm,

The cutting force if both punches act together;

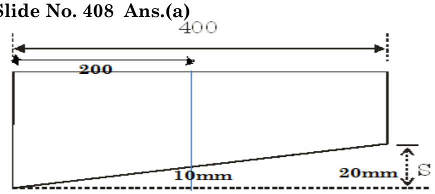
$$F = \frac{(\pi d_1 t\tau + \pi d_2 t\tau) \times pt}{S + pt} = \frac{(\pi 25.4 \times 1.5 \times 280 + \pi \times 12.7 \times 1.5 \times 280) \times 0.6 \times 1.5}{1 + 0.6 \times 1.5} = 23.81 KN$$

GATE-2010 Statement Linked 1 Page No.121 Slide No. 408 Ans.(a)

$t = 5\,mm; L = 200\,mm; \tau = 100 MPa; \frac{p}{t} = 0.2$

$F_{max} = L t\tau = 200 \times 5 \times 100 = 100\,kN$

$Work\ Done = F_{max} \times (pt) = 100 \times (0.2 \times 5) = 100 J$

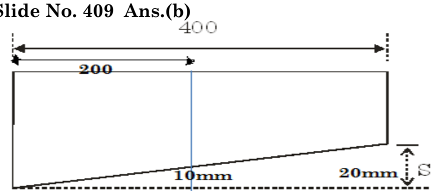


GATE-2010 Statement Linked 2 Page No.121 Slide No. 409 Ans.(b)

For 400mm length shear is 20mm; therefore for 200mm length it becomes10mm. Only 200 mm length is effective.

$F = \frac{F_{max}(pt)}{S}$

$F = \frac{100}{10} = 10 kN$



IAS-2003 Page No.122 Slide No. 419 Ans.(a)

ISRO-2013 Page No.122 Slide No. 420 Ans.(a) Higher the modulus of elasticity higher will be the spring back.

GATE-2011 Page No.123 Slide No. 431 Ans.(c)

Blanking Force(F) $= L t\tau = \pi d t\tau = \pi \times 100 \times 1.5 \times 300 = 141.371 kN$

GATE-2016 Page No.123 Slide No. 432 Ans. 5.026 KN

$F = \pi d t\tau = \pi \times 10 \times 2 \times 80 = 5026\,N = 5.026\,KN$

GATE-2009(PI) Page No.124 Slide No.433 Ans.(b)

Blanking Force(F) $= L t\tau = \pi d t\tau = \pi \times 200 \times 3.2 \times 150 = 301.592 kN$

GATE-2013(PI) Page No.124 Slide No. 434 Ans.(c)

Blanking Force(F) $= L t\tau = \pi d t\tau = \pi \times 10 \times 2 \times 80 = 5.026 kN$

ISRO-2009 Page No.124 Slide No. 435 Ans.(b)

Blanking Force(F) $= L t\tau = \pi d t\tau = \pi \times 25 \times 10 \times 500 = 392.69 kN$

GATE-2007 Page No.124 Slide No. 436 Ans.(a)

Blanking Force(F) $= L t\tau = \pi d t\tau$

$F_1 = 5 = \pi d t\tau \quad and \quad F_2 = \pi \times 1.5d \times 0.4t \times \tau$

$$\frac{F_1}{F_2} = \frac{\pi d t\tau}{\pi \times 1.5d \times 0.4t \times \tau} \quad or \frac{5}{F_2} = \frac{1}{1.5 \times 0.4} \quad or\, F_2 = 3$$

GATE-2004 Page No.124 Slide No.437 Ans.(a)

The blanking force (F_{max})$= \pi d t\tau = \pi \times 10 \times 3 \times 400 = 37.7\,kN$

$$F = \frac{F_{max} \times pt}{S} = \frac{37.7 \times 0.40 \times 3}{2} = 22.6\,kN$$

GATE_2012 Page No.124 Slide No. 438 Ans.(a)

Punch size without allowance = Die size – 2 x radial clearance = 25 – 2 x 0.06 = 24.88 mm

We need another gap (die allowance) i.e. final punch size will be = 24.88 – 0.05 = 24.83 mm

GATE-2008(PI) Page No.124 Slide No. 439 Ans.(c)

C = 6% of t = 0.06×2.5 mm = 0.15 mm

Punch size = die size - 2C = 50 - 2×0.15 mm = 49.70 mm

Die size = 50.00 mm

GATE-2002 Page No.124 Slide No.440 Ans.(c)

GATE-2001 Page No.124 Slide No. 441 Ans.(b)

GATE-1996 Page No.125 Slide No. 442 Ans.(d) Clearance only on punch for Blanking operation. Due to insufficient data we cant calculate.

IES-1994 Page No.125 Slide No. 443 Ans.(a)

IES-2002 Page No.125 Slide No.444 Ans.(b)

IAS-1995 Page No.125 Slide No. 445 Ans.(c)

IES-2006 Page No.125 Slide No. 446 Ans.(c)

IES-2004 Page No.125 Slide No. 447 Ans.(a)

IES-1997 Page No.125 Slide No. 448 Ans.(a)

IAS-2000 Page No.125 Slide No. 449 Ans.(d)

It is blanking operation so clearance must be provided on punch.

Therefore, Die size = blank size = 30 mm

Punch size = blank size – 2C = 30 -2 x 0.06 x t = 30 – 2 x 0.06 x 10 = 28.8 mm

GATE-2007(PI) Page No.125 Slide No. 450 Ans.(c)

$C = 40\,microns = 0.040\,mm; 2C = 0.08\,mm$

$It\ is\ blanking\ operation: Punch\ size = 35 - 0.080\,mm\ and\ Die\ size = 35\,mm$

IAS-1994 Page No.126 Slide No. 451 Ans.(a)

Work done = $F_{max} \times pt = 200\,kN \times 0.25 \times 4 = 200 J \quad [2 \times 10^5 N = 200 kN]$

IAS-2002 Page No.126 Slide No. 452 Ans.(a) In punching usable part is sheet so punch size is Correct and clearance on die. In blanking usable part is punched out circular part so die size is correct and clearance on punch

IAS-2007 Page No.126 Slide No. 453 Ans.(b) In punching useable part is punched sheet so size of hole must be accurate i.e. size of punch must be accurate. Clearance have be given on Die only.

IAS-1995 Page No.126 Slide No. 454 Ans.(a) Both A and R are true and R is the correct explanation of A

IES-2002, GATE(PI)-2003 Page No.126 Slide No. 455 Ans.(c)

IAS-2003 Page No.126 Slide No. 456 Ans.(c)

IES-2000 Page No.126 Slide No. 457 Ans.(b)

IES-1999 Page No.126 Slide No. 458 Ans.(d) In blanking operation clearance is always given on the punch . Die size is always the exact dimension

IES-1994 Page No.127 Slide No. 464 Ans.(c)

$d = 25mm; h = 15mm; We\ know(D) = \sqrt{d^2 + 4dh} = \sqrt{25^2 + 4 \times 25 \times 15} = 46\,mm$

GATE-2003 Page No.127 Slide No. 465 Ans.(c)

Here $\frac{d}{r} = \frac{100}{0.4} = 250$ For $d \geq 20r$; $D = \sqrt{d^2 + 4dh} = \sqrt{100^2 + 4 \times 100 \times 100} = 224\,mm$

GATE-2017 Page No.127 Slide No. 466 Ans.(28.723mm)

ISRO-2011 Page No.127 Slide No. 467 Ans.(a)

IAS-2013(mains) Page No.128 Slide No. 472 Ans.

$d = 50\ mm; h = 100\ mm; BlankDia(D) = \sqrt{d^2 + 4dh} = \sqrt{50^2 + 4 \times 50 \times 100} = 150\,mm$

Reduction $= 1 - \frac{d}{D}$; 1^{st} Reduction; $0.4 = 1 - \frac{d}{150} \Rightarrow d = 90\,mm$

So, it can't be draw in a single draw.

IFS-2013 Page No.128 Slide No. 473 Ans.

$d = 40\,mm; h = 60\,mm; r = 2\,mm$

$D = \sqrt{d^2 + 4dh} = \sqrt{40^2 + 4 \times 40 \times 60} = 105.83\,mm$

First draw 50% reduction, d_1 = 0.5D=52.415mm

Second draw 30% reduction, $d_2 = 0.6d_1 = 31.44\,mm$ (possible)

It is not possible to draw the cup in single step. we have to use double step.

IES-2008 Page No.128 Slide No. 475 Ans.(c) A cylindrical vessel with flat bottom can be deep drawn by double action deep drawing

IES-1997 Page No.129 Slide No. 479 Ans.(c)

$D = \sqrt{d^2 + 4dh} = 15\ cm$

First draw 50% reduction, $d_1 = 7.5$ cm
Second draw 30% reduction, $d_2 = 5.25$ cm
Third draw 25% reduction, $d_3 = 3.94$ cm possible

IES-1998 Page No.129 Slide No. 480 Ans.(d)

$\frac{d}{D} = 0.5; \quad \text{Reduction} = \left(1 - \frac{d}{D}\right) \times 100\% = 50\%$

Thumb rule:

First draw: Reduction = 50%

Second draw: Reduction = 30%

Third draw: Reduction = 25%

Fourth draw: Reduction = 16%

Fifth draw: Reduction = 13%

IAS-1996 Page No.130 Slide No.487 Ans. (a)

IAS-2007 Page No.130 Slide No. 490 Ans.(d) In drawing operation, proper lubrication is essential for

1. To improve die life.
2. To reduce drawing forces.
3. To reduce temperature.
4. To improve surface finish.

IES-1999 Page No.130 Slide No. 494 Ans. (b)

GATE-2008 Page No.131 Slide No. 499 Ans.(a) An insufficient blank holder pressure causes wrinkles to develop on the flange, which may also extend to the wall of the cup.

IAS-1997 Page No.131 Slide No. 500 Ans.(c)

GATE-1999 Page No.131 Slide No. 501 Ans.(b) It is without a blank holder, so no stress.

GATE-2006 Page No.131 Slide No. 502 Ans.(d)

IES-1999 Page No.131 Slide No. 503 Ans.(b)

IAS-1994 Page No.131 Slide No. 504 Ans.(d)

GATE-1992 Page No.132 Slide No. 510 Ans.(a)

$t_c = 1.5mm; \alpha = 30° \quad now\left(t_c\right) = t_b \sin\alpha; \quad or \quad 1.5 = t_b \sin 30 \Rightarrow t_b = 3\,mm$

IES-1994 Page No.132 Slide No. 511 Ans.(d) Mode of deformation of metal during spinning is bending and stretching.

IES-2016 Page No.134 Slide No. 525 Ans.(a)

IES-2011 Page No.134 Slide No. 526 Ans.(b)

Option (b) Magnetic pulse forming and (d) Eletro-hydraulic formingboth are High Energy Rate Forming (HERF). But Question is "usedfor forming components form thin metal sheets or deform thin tubes"it is done by Magnetic pulse forming only.

JWM-2010 Page No.134 Slide No. 527 Ans.(c)

IES-2010 Page No.134 Slide No. 528 Ans.(c)

IES-2007 Page No.134 Slide No. 529 Ans.(b)

High-Energy-Rate-Forming is metal forming through the application of large amount of energy in a very sort time interval.

High energy-release rate can be obtained by five distinct methods:
(i) Underwater explosions.
(ii) Underwater spark discharge (electro-hydraulic).
(iii)Pneumatic-mechanical means.

(iv)Internal combustion of gaseous mixtures.
(v) Electro-magnetic (the use of rapidly formed magnetic fields)

IES-2009 Page No.134 Slide No. 530 Ans.(b)

IES-2005 Page No.134 Slide No. 531 Ans.(c)

GATE-2000 Page No.135 Slide No. 537 Ans.(b)

For bi-axial stretching of sheets: $\varepsilon_1 = \ln\frac{l_{i1}}{l_{o1}} \ and\ \varepsilon_2 = \ln\frac{l_{i2}}{l_{o2}}$

Final thickness $= \frac{initial\ thickness(t)}{e^{\varepsilon_1} \times e^{\varepsilon_2}}$

$t = 1.5mm; \varepsilon_1 = 0.05; \varepsilon_2 = 0.09 \therefore \text{Final thickness} = \frac{1.5}{e^{0.05} \times e^{0.09}} = 1.304\,mm$

IES-1998 Page No.136 Slide No. 547 Ans.(a)

EXAMPLE Page No. 136 Slide No. 548 Ans.

$$F = \frac{Kl\sigma_{ut}t^2}{w}$$

$$= \frac{1.33 \times 1200 \times 455 \times 1.6^2}{12.8} N = 145.24\,kN$$

GATE-2005 Page No.136 Slide No. 549 Ans.(c)

$\alpha = 1\,radian; R = 100mm; k = 0.5; t = 2mm$

$L_b = \alpha(R + kt) = 1(100 + 0.5 \times 2) = 101\,mm$

GATE-2007 Page No.137 Slide No. 553 Ans.(d)

GATE -2012 Same Q in GATE-2012 (PI) Page No.123 Slide No.554 Ans.(a)

GATE-2004 Page No.137 Slide No. 555 Ans.(b)

IAS-1999 Page No.137 Slide No. 556 Ans.(d)

IAS-1997 Page No.137 Slide No. 557 Ans.(c)

IES-2010 Page No.137 Slide No. 558 Ans.(d)

Ch-12 Powder Metallurgy: Answers with Explanations

IAS-2003 Page No.138 Slide No.562 Ans. (c) It is for low melting point temperature metals.

IAS-2007 Page No.138 Slide No.563 Ans. (c) In atomization process inert gas or water may be used as a substitute for compressed air.

IES-2016 Page No.138 Slide No.564 Ans. (c)

- Molten metal is forced through a small orifice and is disintegrated by a jet of compressed air, inert gas or water jet.
- In atomization, the particles shape is determined largely by the rate of solidificationand varies from spherical, if a low-heat-capacity gas is employed, to highly irregularif water is used. By varying the design and configurations of the jets pressure andvolume of the atomizing fluid, thickness of the stream of metal, etc, it is possibleto control the particle size distribution over a wild range.

IES-1999 Page No.138 Slide No.565 Ans. (c) An oxide film is formed in the case of air atomization and that film can be avoided by using an inert gas.

GATE-2017(PI) Page No.138 Slide No.566 Ans. (a)

GATE-2011(PI) Page No.139 Slide No.568 Ans. (b) In reduction Metal oxides are turned to pure metal powder when exposed to below melting point gases results in a product of cake of sponge metal.

IES-2012 Page No.139 Slide No.573 Ans. (b)

GATE -2014 (PI) Page No.139 Slide No.575 Ans. (b) Compaction is used for making product.

IAS-2000 Page No.139 Slide No.576 Ans. (b) Sintering used for making bond

IES-2010 Page No.140 Slide No.577 Ans. (d)

IES-1999 Page No.140 Slide No.578 Ans. (a)

IES-2013(conventional) Page No.140 Slide No.582 Ans. Lubricants such as graphite or stearic acid improve the flow characteristics and compressibility at the expense of reduced strength.

GATE-2016(PI) Page No.141 Slide No.589 Ans. (c)

GATE-2010(PI) Page No.141 Slide No.590 Ans. (b) Due to formation of bonding brittleness reduces.

IES-2002 Page No.141 Slide No.591 Ans. (c)

IAS-1997 Page No.142 Slide No.597 Ans. (d) A is false. Closed dimensional tolerances are possible with iso-static pressing of metal power in powder metallurgy technique.

ISRO-2013 Page No.143 Slide No. 605 Ans. (b& c) Best choice will be (c)

GATE-2009(PI) **Page No.143 Slide No.610 Ans. (d)**
IES-2007 **Page No.143 Slide No.611 Ans. (b)**Disadvantage of PM is relatively high die cost.
IES-2012 **Page No.144 Slide No.613 Ans. (b)**
IES-2006 **Page No.144 Slide No.613 Ans. (c)**No wastage of material.It may be automated though it is difficult for automation. this is not true
IES-2004 **Page No.144 Slide No.613 Ans. (a)**
IES-2010 **Page No.144 Slide No.618 Ans. (c)**
IAS-1998 **Page No.144 Slide No.619 Ans. (c)**
IES-2009 **Page No.144 Slide No.620 Ans. (c)**
GATE-2011(PI) Page No144 Slide No.621 Ans. (d)
IAS-2003 **Page No.145 Slide No.622 Ans. (a)**
IES-1997 **Page No.145 Slide No.623 Ans. (d)**
IES-2001 **Page No.145 Slide No.624 Ans. (b)**
IES-2015 **Page No.145 Slide No. 625 Ans. (b)**
IAS-2003 **Page No.145 Slide No.627 Ans. (d)**
GATE-2011 **Page No.146 Slide No.633 Ans. (c)**
IAS-1996 **Page No.146 Slide No.634 Ans. (b)**
IES-1998 **Page No.146 Slide No.635 Ans. (b)**
IES-2014 **Page No.146 Slide No.636 Ans. (c)**
IAS-2007 **Page No.146 Slide No.637 Ans. (b)**
IAS-2004 **Page No.146 Slide No.638 Ans. (b)**
IES-2001 **Page No.146 Slide No.639 Ans. (d)**
GATE-2008(PI) **Page No.147 Slide No.640 Ans. (d)**

Ch-xx Tool Materials: Answers with Explanations

IAS-1997 **Page No.148 Slide No.7 Ans.(a)**Carbon steel tools have Limited tool life. Maximum cutting speeds about 8 m/min. dry and used upto 250°C
IES-2013 **Page No.149 Slide No.11 Ans.(b)** Addition of large amount of cobalt and Vanadium to increase hot hardness and wear resistance respectively
IAS-1997 **Page No.149 Slide No.12 Ans.(a)**Coating if TiC and TiN on HSS is done by by Chemical Vapour Deposition (CVD) or Physical Vapour Deposition (PVD)
IES-2003 **Page No.149 Slide No.14 Ans.(a)**18-4-1 High speed steel- contains 18 per cent tungsten, 4 per cent chromium and 1 per cent vanadium
IES-2007 **Page No.149 Slide No.15 Ans.(a)**
IES-1993 **Page No.149 Slide No.16 Ans.(b)**The blade of a power saw is made of high speed steel.
IES-1995 **Page No.150 Slide No.19 Ans.(d)**

- 18-4-1 **High speed steel**- contains 18 per cent tungsten, 4 per cent chromium and 1 per cent vanadium
- **Molybdenum high speed steel** contains 6 per cent tungsten, 6 per cent molybdenum, 4 per cent chromium and 2 per cent vanadium.

IES-2000 **Page No.150 Slide No.20 Ans.(b)**
IES-1992 **Page No.150 Slide No.21 Ans.(a)**
IAS-2001 **Page No.150 Slide No.22 Ans.(a)**
IAS-1994 **Page No.150 Slide No.23 Ans.(b)**
IES-2011 **Page No.150 Slide No.27 Ans.(a)**
IES-1995 **Page No.151 Slide No.33 Ans.(c)**
IAS-1994 **Page No.151 Slide No.34 Ans.(a)**
IES-1999 **Page No.152 Slide No.38 Ans.(c)**
IES-2016 **Page No.152 Slide No.45 Ans. (b)**

Creamics tool is sued upto 1300°C SiC can with stand upto 2700°C that so why we can use it for furnace part also. But statement-I and statement-II has no relation.
IES-2013 **Page No.153 Slide No.47 Ans.(a)**
IES-2010 **Page No.153 Slide No.48 Ans.(b)**Constituents of ceramics are oxides of different materials, which areGround, sintered and palleted to make ready ceramics
IAS-1996 **Page No.153 Slide No.49 Ans.(c)**
IES-1997 **Page No.153 Slide No.50 Ans.(b)**Ceramic tools are used only for light, smooth and continuous cuts at high speeds.This is because of low strength of ceramics

IES-1996 **Page No.153 Slide No.51 Ans.(b)**

$$V = \frac{\pi D(mm) N}{1000} m/\min = \frac{\pi \times 100 \times 1000}{1000} = 314.15 m/\min$$

Cutting speed in this case is 314 m / min, at which ceramic is suited.
IES-2007 **Page No.153 Slide No.52 Ans.(d)**
IAS-2000 **Page No.153 Slide No.53 Ans.(c)**
H.S.S < Cast alloy < Carbide < Cemented carbide < Cermets < ceramics
IAS-2003 **Page No.154 Slide No.54 Ans.(c)**
IAS-1999 **Page No.154 Slide No.59 Ans.(b)**
IES-2010 **Page No.155 Slide No.63 Ans.(c)**
IES-2000 **Page No.155 Slide No.64 Ans.(d)**Cermets are Metal-ceramic composites
IES-2003 **Page No.155 Slide No.65 Ans.(a)**
GATE-2009(PI) **Page No.155 Slide No.67 Ans.(d)**On ferrous materials, diamonds are not suitable because of the diffusion of carbon atoms from diamond to the work-piece material.
IES-1995 **Page No.155 Slide No.70 Ans.(b)**Nonferrous materials are best to work with diamond because ferrous materials have affinity towards diamond and diffusion of carbon atoms takes place.
IES-2001 **Page No.155 Slide No.71 Ans.(b)**
IES-1999 **Page No.140 Slide No.72 Ans.(a)**
IES-1992 **Page No.156 Slide No.73 Ans.(c)**
IAS-1999 **Page No.156 Slide No.74 Ans.(a)**"Oxidation of diamond starts at about 450°C and thereafter it can even crack. For this reason the diamond tool is kept flooded by the coolant during cutting, and light feeds are used." - Book B L Juneja and Nitin seth page 88
IES-1994 **Page No.156 Slide No.78 Ans.(a)**
IES-2002 **Page No.156 Slide No.79 Ans.(d)**
IES-1996 **Page No.156 Slide No.80 Ans.(a)**Hardness of CBN is comparable to diamond
IES-1994 **Page No.157 Slide No.81 Ans.(d)**None of the uses is true for CBN.
IAS-1998 **Page No.157 Slide No.82 Ans.(b)**
IES-1993 **Page No.157 Slide No.84 Ans.(b)**
High speed steel, in addition to W, Cr & V, has Mo as the most influencing constituent. Thus A matches with 2.
Non ferrous alloys (stellites) are high in cobalt. Thus B matches with 5.
The major constituent of diamond is carbon. Thus C matches with 1.
Coated carbide tools are treated by nitriding. Thus D matches with 3
IES-2003 **Page No.157 Slide No.85 Ans.(b)**This is one of the natural abrasives found, and is also called corundum and emery. However, the natural abrasives generally have impurities and, as a result, their performance is inconsistent. Hence the abrasive used in grinding wheels is generally manufactured from the aluminium ore, bauxite,Silicon carbide (SiC) Silicon carbide is made from silica sand and coke with small amounts of common salt.
IES-2000 **Page No.157 Slide No.86 Ans.(b)**Cutting speed of diamond is very high but small feed rate with low depth of cut. Degarmo and Kalpakjian both book written this.
IES-1999 **Page No.157 Slide No.87 Ans.(d)**WC is used for drawing dies, silicone nitride for pipes to carry liquid metal, Al_2O_3 for abrasive wheels, and silicon carbide for heating elements**.**
IAS-2001 **Page No.157 Slide No.88 Ans.(d)**
IES-1996 **Page No.158 Slide No.90 Ans.(a)**
IES-2005 **Page No.158 Slide No.91 Ans.(d)**

Analysis of Forging

True stress and True Strain

The true stress is defined as the ratio of the load to the cross section area at any instant. $(\sigma_T) = \dfrac{\text{load}}{\text{Instantaneous area}} = \sigma(1+\varepsilon)$

Where σ and ε is the engineering stress and engineering strain respectively.

True strain

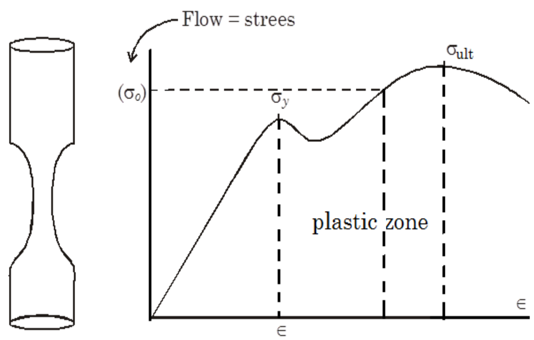
$$(\varepsilon_T) = \frac{\text{Elongation}}{\text{Instantaneous lenght}} = \int_{L_o}^{L} \frac{dx}{x} = \ln\left(\frac{L}{L_o}\right) = \ln(1+\varepsilon) = \ln\left(\frac{A_o}{A}\right) = 2\ln\left(\frac{d_o}{d}\right)$$

or engineering strain (ε) $= e^{\varepsilon_T}$ -1

The volume of the specimen is assumed to be constant during plastic deformation.
[$\because A_o L_o = AL$] It is valid till the neck formation.

Flow Stress

When a material deforms plastically strain hardening occurs.



Forging occurs in plastic zone i.e in between σ_y and σ_{ult}

σ_y – Yield Stress

σ_o – For forging, we need flow stress and flow stress is not constant and depends on stress of the workpiece.

σ_{ult} – Ultimate tensile stress here neck formation starts.

Equation of Flow Curve

(a) With strain hardening

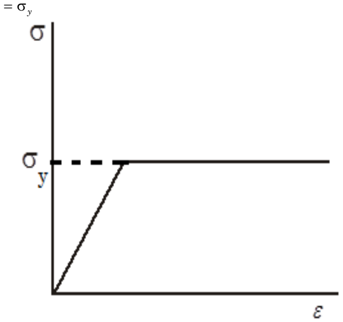
$$\sigma_o = K(\epsilon_T)^n$$

e.g. $\sigma_o = 1000\,(\epsilon_T)^{0.3}$

Here σ_o is flow stress but it is true stress and ε_T is true strain.

(b) Without strain hardening:

$$\sigma_o = \sigma_y$$

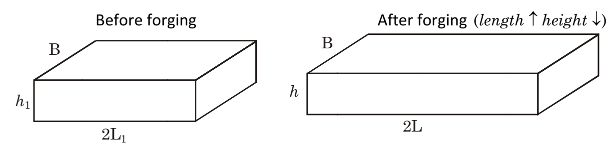


We will analyze only open die forging using slab method of analysis for

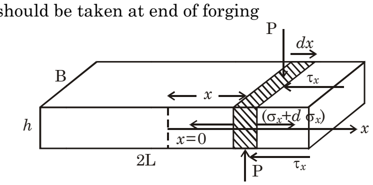
(1) Rectangular Bar forging, and

(2) Axi-symmetric forging

1. Rectangular Bar Forging



- Here we are using plane strain condition *i.e.* width won't increase.
- At the end of the forging, force will be maximum because of the area involved between the die and the workpiece is maximum.
- Geometry should be taken at end of forging



$x = 0$, is the point at which the material does not move in any direction.
Take an element dx at a distance of x (enlarged view):

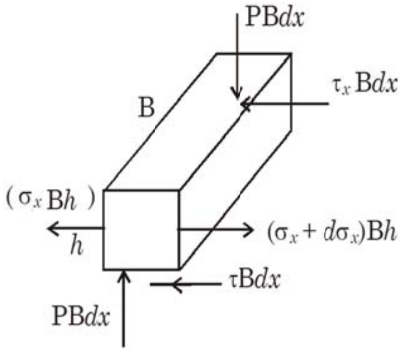


Fig. FBD of Elements

Now element will look like a slab and hence its name slab method of analysis.

- On left side (stress x area) = Force $(\sigma_x \times Bh)$ and on other side force will be $(\sigma_x + d\sigma_x)Bh$.
- Upper die will give pressure on upper surface and lower surface will get pressure by lower die. So on upper side force= P × area = (P × B× dx) & similarly on lower side = $(P\ B\ dx)$
- As metal is moving outwards so friction force will act in opposite direction, this friction force is shear force and will cause shear stress on the surface equal to $(\tau_x\ B\ dx)$ in lower and upper surface.

At the end of forging the system must be in equilibrium; therefore net resultant force in any direction is zero.

$\therefore \quad \Sigma F_x = 0$; Gives

$$(\sigma_x + d\,\sigma_x)\,Bh - \sigma_x\,.\,Bh - 2\tau_x\,.\,B\,dx = 0$$

or $\quad d\,\sigma_x\ Bh - 2\tau_x\ B\,dx = 0$

or $\quad d\,\sigma_x\,.\,h - 2\tau_x\ dx = 0$

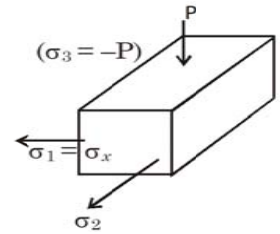
$$\frac{d\sigma_x}{dx} - \frac{2\tau_x}{h} = 0 \qquad (1)$$

Here there are three variables σ_x, τ_x and x so we reduce it into two variables by applying condition.

For a ductile material there are **two theories of plasticity.**

1. Von-Mises Theory: $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\,\sigma_0^2$

2. Tresca's Theory: $\sigma_1 - \sigma_3 = \sigma_0$



As $\quad \epsilon_2 = 0 \quad$ ($\because$ Plane strain condition)

$$\frac{\sigma_2}{E} - \frac{\nu\sigma_1}{E} - \frac{\nu\sigma_3}{E} = 0$$

$$\sigma_2 = \nu(\sigma_1 + \sigma_3)$$

or $\quad \sigma_2 = \nu(\sigma_x - P)$

Note: In theories of plasticity $\left(\text{Poisson's ratio}, \nu = \frac{1}{2}\right)$ as volume change not occur.

Therefore, $\quad \sigma_2 = \frac{1}{2}(\sigma_x - P)$

From Von-Mises theory:

$$\left\{\sigma_x - \frac{1}{2}(\sigma_x - P)\right\}^2 + \left\{\frac{1}{2}(\sigma_x - P) + P\right\}^2 + (-P - \sigma_x)^2 = 2\sigma_0^2$$

or $\quad \frac{(\sigma_x + P)^2}{4} + \frac{(\sigma_x + P)^2}{4} + (\sigma_x + P)^2 = 2\sigma_0^2$

or $\quad \frac{3}{2}(\sigma_x + P)^2 = 2\,\sigma_0^2$

or $\quad (\sigma_x + P)^2 = \frac{4}{3}\sigma_0^2$

or $\quad (\sigma_x + P) = \frac{2}{\sqrt{3}}\sigma_0$

or $\quad \sigma_x + P = 2K \quad$ ….(2) [where $K = \frac{\sigma_0}{\sqrt{3}}$ = flow shear stress]

From Tresca's theory :

$$\sigma_1 - \sigma_3 = \sigma_0$$

or $\quad \sigma_x + P = \sigma_0$

or $\quad \sigma_x + P = 2K \quad$ ….(2) [where $K = \frac{\sigma_0}{2}$ = flow shear stress]

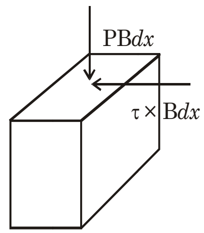
Differentiating equation (2)

$$\frac{d\sigma_x}{dx} + \frac{dP}{dx} = 0$$

or $$\frac{d\sigma_x}{dx} = \frac{-dP}{dx} \quad ....(3)$$

Condition-1:

Considering sliding friction all over the surface ($\tau_x = \mu P$)



$$F = \mu N$$
$$\text{or } dF = \mu dN$$
$$\tau_x \, B dx = \mu . PB \, dx$$
$$\tau_x = \mu P$$

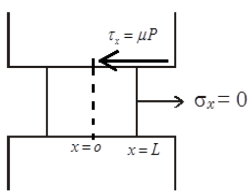
From equation (1) and (3)

$$\frac{d\sigma_x}{dx} - \frac{2\tau_x}{h} = 0$$

or $$-\frac{dP}{dx} - \frac{2\mu P}{h} = 0$$

or $$\int \frac{dP}{P} = -\frac{2\mu}{h} \int dx$$

or $$\ln P = -\frac{2\mu}{h} x + C \quad ......(4)$$



Boundary conditions, at $x = L$, $\sigma_x = 0$ (because no force is applied so no stress on that surface) and $\sigma_x + P = 2K$ gives $P = 2K$

or $$\ln(2K) = -\frac{2\mu}{h} L + C$$

or $$C = \ln(2K) + \frac{2\mu}{h} . L$$

Putting the values of C in equation (4)

$$\ln P = -\frac{2\mu}{h} x + \ln(2K) + \frac{2\mu}{h} . L$$

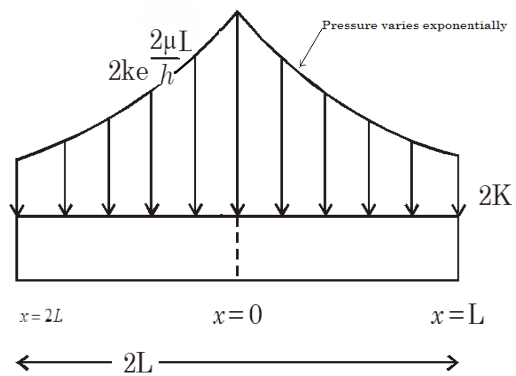
or $$\ln\left(\frac{P}{2K}\right) = \frac{2\mu}{h}(L - x)$$

or $$\ln\left(\frac{P}{2K}\right) = \frac{2\mu}{h}(L - x)$$

or $$P = 2K . \, e^{\frac{2\mu}{h}(L - x)} \quad .... (5) \text{ (Pressure distribution equation)}$$

At $x = 0$, $P_{max} = 2K \, e^{\frac{2\mu}{h}(L)}$

At $x = L$, $P_{min} = 2K \, e^{\frac{2\mu}{h}(0)} = 2K$



Elemental force, $dF = P.B.dx$

$$dF = 2K \, e^{\frac{2\mu}{h}(L-x)} . B.dx$$

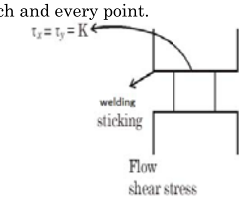
Integrating, $F = 2 \times \int_0^L (2K . e^{\frac{2\mu}{h}.(L-x)} . B . dx)$ $\left(\because \int_0^L \text{ gives half portion F so for 2L we use } 2\int_0^L \right)$

$$F = 4KB . \int_0^L e^{\frac{2\mu}{h}(L-x)} . dx$$

Condition-2:

Considering sticking friction all over the surface ($\tau_x = \tau_y = K$)

Shear failure will occur at each and every point.



From equation (1) and (3)

$$\frac{d\sigma_x}{dx} - 2\frac{\tau_x}{h} = 0$$

or $$-\frac{dP}{dx} - \frac{2K}{h} = 0$$

or $$\int dP = \frac{-2K}{h} \int dx$$

or $$P = -\frac{2K}{h} x + C \quad ......(6)$$

Boundary conditions, at x = L, $\sigma_x = 0$ (because no force is applied so no stress on that surface) and $\sigma_x + P = 2K$ gives P = 2 K

So, $$2K = -\frac{2KL}{h} + C$$

or $$C = 2K + \frac{2K}{h}.L$$

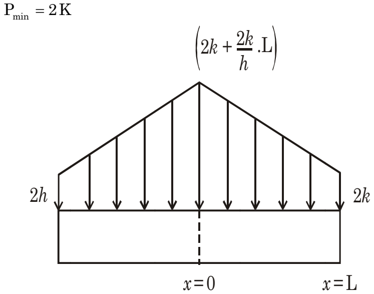
Putting in equation (6)

$$P = -\frac{2K}{h}.x + 2K + \frac{2K}{h}.L$$

$$P = 2K + \frac{2K}{h}(L - x) \quad \text{........ (7) \{Pressure distribution equation\}}$$

At $x = 0$, $P_{max} = 2K + \frac{2K}{h}.L$

$x = L$, $P_{min} = 2K$



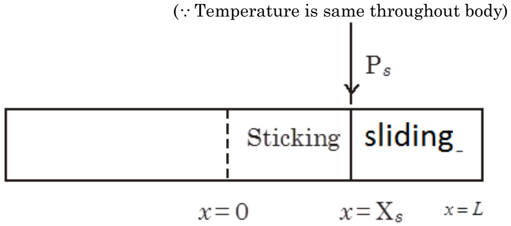
Elemental force, $dF = P.B.dx$

or $$dF = \left\{2K + \frac{2K}{h}(L - x)\right\}B.dx$$

$$F = 2 \times \int_0^L \left\{2K + \frac{2K}{h}(L - x)\right\}B.dx$$

Condition-3:
Considering sticking and sliding both model of friction

(∵ Temperature is same throughout body)



For Sliding Region: $\frac{d\sigma_x}{dx} - \frac{2\tau_x}{h} = 0$

or $$-\frac{dP}{dx} - \frac{2\mu P}{h} = 0$$

or $$\int \frac{dP}{P} = -\frac{2\mu}{h}\int dx$$

or $$\ln P = -\frac{2\mu}{h}x + C \quad \text{......(4)}$$

Boundary conditions, at x = L, $\sigma_x = 0$ (because no force is applied so no stress on that surface) and $\sigma_x + P = 2K$ gives P = 2 K

or $$\ln(2K) = -\frac{2\mu}{h}L + C$$

or $$C = \ln(2K) + \frac{2\mu}{h}.L$$

Putting the values of C in equation (4)

$$\ln P = -\frac{2\mu}{h}x + \ln(2K) + \frac{2\mu}{h}.L$$

or $$\ln\left(\frac{P}{2K}\right) = \frac{2\mu}{h}(L - x)$$

or $$\ln\left(\frac{P}{2K}\right) = \frac{2\mu}{h}(L - x)$$

or $$P = 2K.\, e^{\frac{2\mu}{h}(L - x)} \quad \text{.... (5)}$$

For Sticking Region: $\frac{d\sigma_x}{dx} - 2\frac{\tau_x}{h} = 0$

or $$-\frac{dP}{dx} - \frac{2K}{h} = 0$$

or $$\int dP = \frac{-2K}{h}\int dx$$

or $$P = -\frac{2K}{h}x + C \quad \text{......(6)}$$

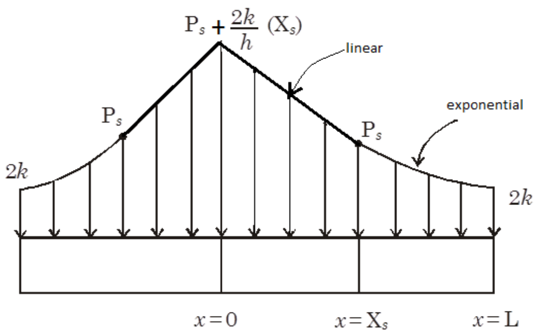
At $x = x_s$; $P = P_s$

or $$P_s = -\frac{2K}{h}x_s + C$$

or $$C = P_s + \frac{2K}{h}.x_s$$

$$P = -\frac{2K}{h}x + P_s + \frac{2K}{h}x_s$$

$$P = P_s + \frac{2K}{h}(x_s - x) \quad \text{..............(8)}$$



$$F_{Total} = F_{Sticking} + F_{Sliding}$$

$$= 2\int_0^{X_s} P_{Sticking} \, . \, B \, . \, dx + 2\int_{X_s}^{L} P_{Sliding} \, . \, B \, dx$$

$$= 2\int_0^{x_s} \left\{ P_s + \frac{2K}{h}(x_s - x) \right\} B \, . \, dx + 2\int_{x_s}^{L} \left\{ 2K \, e^{\frac{2\mu}{h}(L-x)} \right\} B \, . \, dx$$

To find P_s and x_s

At $x = x_s$, Shear stresses are same for both sticking and sliding

$\tau_x = K$ (if considering sticking)

$\tau_x = \mu P_s$ (if considering sliding)

$\tau_x = K = \mu P_s$

$$P_s = \frac{K}{\mu} \quad \text{....(9)}$$

At $x = x_s$; $P = P_s$

$$P_s = 2K \, e^{\frac{2\mu}{h}(L-x_s)}$$

or

$$\frac{K}{\mu} = 2K \, e^{\frac{2\mu}{h}(L-x_s)}$$

or

$$\frac{1}{2\mu} = e^{\frac{2\mu}{h}(L-x_s)}$$

or

$$\ln\left(\frac{1}{2\mu}\right) = \frac{2\mu}{h}(L - x_s)$$

$$\frac{h}{2\mu} \, . \, \ln\left(\frac{1}{2\mu}\right) = L - x_s$$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) \quad \text{....(10) (in any question first we find this } x_s\text{)}$$

Using this equation we can decide the condition of friction.

Example 1: L = 50 mm, h = 10 mm & $\mu = 0.25$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) = 50 - \frac{10}{2\times 0.25}\ln\left(\frac{1}{2\times 0.25}\right) = 36.13\,mm$$

0 to 36.13 mm sticking and 36.13 mm to 50 mm sliding will take place.

Example 2: L = 50 mm, h = 10 mm & $\mu = 0.08$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) = 50 - \frac{10}{2\times 0.08}\ln\left(\frac{1}{2\times 0.08}\right) = -64.53\,mm\,(\text{absurd value})$$

($\because x$ cannot be –ve) i.e only sliding no sticking occur.

Example 3: L = 50 mm, h = 10 mm & $\mu = 0.65$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) = 50 - \frac{10}{2\times 0.65}\ln\left(\frac{1}{2\times 0.65}\right) = 52.01\,mm$$

Only sticking no sliding

NOTE: If $\mu > 0.5$ then only sticking, In hot forging (μ) is larger if $\mu > 0.5$ only sticking condition will occur.

IES – 2005 Conventional

A strip of lead with initial dimensions 24 mm x 24 mm x 150 mm is forged between two flat dies to a final size of 6 mm x 96 mm x 150 mm. If the coefficient of friction is 0.25, determine the maximum forging force. The average yield stress of lead in tension is 7 N/mm²

Solution: h = 6 mm, 2L = 96 mm, $\mu = 0.25$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) = 48 - \frac{6}{2\times 0.25}\ln\left(\frac{1}{2\times 0.25}\right) = 39.68\,mm$$

$$F_{total} = 2\times\int_0^{x_S} \left\{ P_s + \frac{2K}{h}(x_s - x) \right\} B. \, dx + 2\times\int_{x_S}^{L} 2K \, e^{\frac{2\mu}{h}(L-x)} \, B \, . \, dx$$

Applying Von-Mises theory $K = \frac{\sigma_0}{\sqrt{3}} = 4.04\,N/mm^2$

$$P_s = \frac{K}{\mu} = 16.16\,N/mm^2$$

or

or

$$F = 2\times\int_0^{39.68} \left\{ 16.16 + \frac{2\times 0.25}{6}(39.68 - x) \right\} \cdot 150 \, . \, dx + 2\times\int_{39.68}^{48} (2\times 4.04)\, e^{\frac{2\times 0.25}{6}(48-x)} \cdot 150 \, . \, dx$$

$$= 510 \text{ kN} + 29.10\,kN = 539\,\text{kN}\,(Von - Mises)$$

Applying Tresca's Theory, $K = \frac{\sigma_o}{2} = 3.5\,N/mm^2$; $P_s = \frac{K}{\mu} = \frac{3.5}{0.25} = 14\,N/mm^2$

$$F = 2\times\int_0^{39.68} \left\{ 14 + \frac{2\times 3.5}{6}(39.68 - x) \right\} \cdot 150 \cdot dx + 2\int_{39.68}^{48} (2\times 3.5)\, e^{\frac{2\times 0.25}{6}(48-x)} \cdot 150 \cdot dx$$

$$442\,kN + 25\,kN = 467\,kN\,(Tresca's)$$

Practice Problem-1

A strip of metal with initial dimensions 24 mm x 24 mm x 150 mm is forged between two flat dies to a final size of 6 mm x 96 mm x 150 mm. If the coefficient of friction is 0.05, determine the maximum forging force. Take the average yield strength in tension is 7 N/mm²

Given: 2L = 96 mm; L = 48 mm; h = 6 mm; B = 150 mm; $\mu = 0.05$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) \qquad K = 4.04 \text{ N/mm}^2$$

$$x_s = -90.155\,mm$$

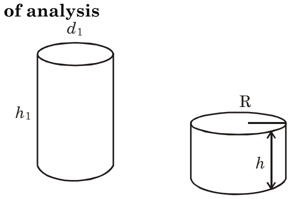
Since x_s came negative so there will be no sticking only sliding will take place.

$$F = 4\,KB\int_0^L e^{\frac{2\mu}{h}(L-x)}\,dx$$

$$= 4\times 4.04\times 150\int_0^{48} e^{\left\{\left(\frac{2\times 0.05}{6}\right)(48-x)\right\}}\,dx = 177.98\text{ kN}$$

Axi – Symmetrical Forging (Open Die):

Using cylindrical co-ordinate system (r, θ, z)
and Using Slab Method of analysis



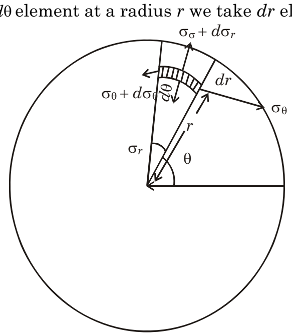
At the start of forging

At end of forging

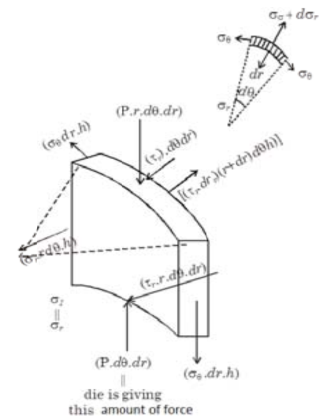
Volume before forging = Volume after forging

$$\frac{\pi}{4}d_1^2\times h_1 = \pi R^2 h$$

At an angle θ, we take an $d\theta$ element at a radius r we take dr element.

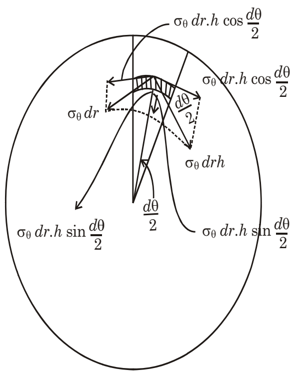


For axi-symmetrical forging $d\sigma_\theta$ will be zero.



Net resultant force in radially outward direction is 0.

$$(\sigma_r + d\,\sigma_r)\,(r+dr)\,d\theta\,.\,h - (\sigma_r\,.\,r\,d\theta\,.\,h) - 2\,\tau_r\,.\,r\,d\theta\,.\,dr - 2\,\sigma_\theta\,dr\,h\,.\sin\frac{d\theta}{2} = 0$$



$$\left(\cos\frac{d\theta}{2}\text{ gets cancelled} \therefore \text{they are opposite}\right)$$

For Axi-Symmetry forging

$\epsilon_r = \epsilon_\theta$

i.e. $\sigma_r = \sigma_\theta$

From above equation,

$$(\sigma_r + d\,\sigma_r)\,(r+dr)\,d\theta\,.\,h - (\sigma_r\,.\,r\,d\theta\,.\,h) - 2\,\tau_r\,.\,r\,d\theta\,.\,dr - 2\,\sigma_r\,dr\,h\,.\,\frac{d\theta}{2} = 0$$

$$\left(\text{Using}: \sigma_\theta = \sigma_r;\ \sin\frac{d\theta}{2}\approx\frac{d\theta}{2}\right)$$

or $$(\sigma_r + d\,\sigma_r)\,(r+dr)\,.\,h - (\sigma_r\,.\,rh) - 2\tau_r\,.\,r\,dr - \sigma_r\,.\,dr\,.\,h = 0$$

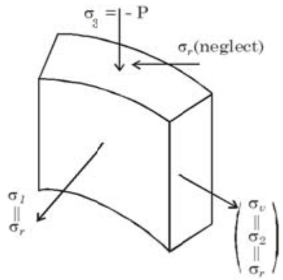
or $(\sigma_r . r . h + d\sigma_r . rh + d\sigma_r . drh + \sigma_r\, dr . h) - \sigma_r . rh - 2\tau_r . r\, dr - \sigma_r\, dr . h = 0$

or $d\,\sigma_r . r\, h = 2\tau_r . r\, dr$

or $\frac{d\,\sigma_r}{dr} - \frac{2\,\tau_r}{h} = 0$ ...(1)

For ductile material there are two theories of plasticity

1. Tresca's Theory:



$$\sigma_1 - \sigma_3 = \sigma_0$$

or $\sigma_r + P = \sigma_0$ ...(2)

2. Von Miscs Theory:

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\,\sigma_0^2$$

or $(\sigma_r - \sigma_r)^2 + (\sigma_r + P)^2 + (-P - \sigma_r)^2 = 2\,\sigma_0^2$

or $2\,(\sigma_r + P)^2 = 2\,\sigma_0^2$

or $\sigma_r + P = \sigma_0$ ...(2)

On differentiating;

$$\frac{d\,\sigma_r}{dr} + \frac{dP}{dr} = 0$$

$$\frac{d\,\sigma_r}{dr} = -\frac{dP}{dr} \quad ...(3)$$

Condition 1:
Considering sliding friction all over the surface

$$\tau_r = \mu P$$

From (1) and (3); $-\frac{dP}{dr} - \frac{2\tau_r}{h} = 0$

or $-\frac{dP}{dr} - 2 . \frac{\mu P}{h} = 0$

or $\frac{dP}{dr} = \frac{-2\,\mu P}{h}$

or $\int \frac{dP}{P} = -\int \frac{2\,\mu}{h} . dr$

$$\ln P = -\frac{2\,\mu}{h} . r + C \quad ...(4)$$

At $r = R$; $\sigma_r = 0$ (because on this surface there will be no force) and $\sigma_r + P = \sigma_0$; $P = \sigma_0$

or $\ln \sigma_0 = -\frac{2\mu . R}{h} + C$

or $C = \ln \sigma_0 + \frac{2\,\mu R}{h}$

From equation (4) $\ln P = -\frac{2\,\mu\, r}{h} + \ln \sigma_0 + \frac{2\,\mu R}{h}$

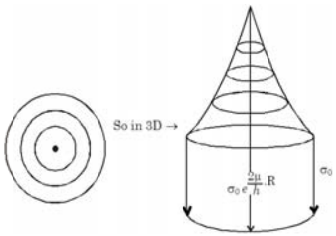
or $\ln \frac{P}{\sigma_0} = \frac{2\mu}{h}(R - r)$

or $P = \sigma_0 . e^{\frac{2\mu}{h}(R-r)}$ .... (5) Pressure distribution

At $r = 0$; $P_{max} = \sigma_0\, e^{\frac{2\mu}{h} . R}$

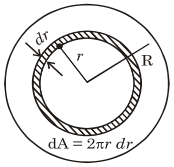
At $r = R$; $P_{min} = \sigma_0$

Here $r = 0$ means a point



For finding force

Elemental force (dF)



$$dF = dF = P . 2\pi r . dr$$

$$\int dF = \int \sigma_0 . e^{\frac{2\mu}{h}(R-r)} . 2\pi r . dr$$

or $F = 2\pi\sigma_0 \int_0^R r.e^{\frac{2\mu}{h}.(R-r)}\, dr$

or $F = 2\pi\sigma_0 \left[\frac{r . e^{\frac{2\mu}{h}(R-r)}}{\left(-\frac{2\mu}{h}\right)} - \int \left(1 . \frac{e^{\frac{2\mu}{h}(R-r)}}{\left(-\frac{2\mu}{h}\right)} dr\right) \right]_0^R$

or $F = 2\pi\sigma_0 \left[\frac{r . e^{\frac{2\mu}{h}(R-r)}}{\left(-\frac{2\mu}{h}\right)} - \frac{e^{\frac{2\mu}{h}(R-r)}}{\left(-\frac{2\mu}{h}\right)^2} \right]_0^R$

or $F = 2\pi\,\sigma_0 \left[\frac{R}{\left(\frac{-2\mu}{h}\right)} - \frac{1}{\left(\frac{-2\mu}{h}\right)^2} - 0 + \frac{e^{\frac{2\mu}{h}R}}{\left(\frac{-2\mu}{h}\right)^2} \right]$

IES – 2007 Conventional

A cylinder of height 60 mm and diameter 100 mm is forged at room temperature between two flat dies. Find the die load at the end of compression to a height 30 mm, using slab method of analysis. The yield strength of the work material is given as 120 N/mm² and the coefficient of friction is 0.05. Assume that volume is constant after deformation. There is no sticking. Also find mean die pressure. **[20-Marks]**

Solution: Given, $h_1 = 60$ mm, $d_1 = 100$ mm, h = 30 mm

$\sigma_0 = 120\ \text{N/mm}^2$ and $\mu = 0.05$

or $\quad \dfrac{\pi d_1^2}{4} h_1 = \pi R^2 h$

or $\quad \dfrac{100^2}{4} \times 60 = R^2 \times 30$

or $\quad R = 70.7$ mm

$$F = 2\pi\,\sigma_0 \left[\frac{R}{\left(\frac{-2\mu}{h}\right)} - \frac{1}{\left(\frac{-2\mu}{h}\right)^2} - 0 + \frac{e^{\frac{2\mu}{h}.R}}{\left(\frac{-2\mu}{h}\right)^2} \right] = 2.04\ MN$$

$$\text{Mean Die pressure} = \frac{\text{Total force}}{\text{Total Area}} = \frac{2.04 \times 10^6}{\pi \times 70.7^2} \approx 130\ MPa$$

GATE – 2014 (PI)

In an open die forging, a circular disc is gradually compressed between two flat platens. The exponential decay of normal stress on the flat face of the disc, from the center of the disc towards its periphery, indicates that

(a) there is no sticking friction anywhere on the flat face of the disc

(b) sticking friction and sliding friction co-exist on the flat face of the disc

(c) the flat face of the disc is frictionless

(d) there is only sticking friction on the flat face of the disc

Answer: (a)

Condition -2: Considering sticking friction all over the surface

$\tau_r = K$

From (1) equation (3)

$$\frac{d\sigma_r}{dr} - \frac{2\tau_r}{h} = 0$$

or $\quad -\dfrac{dP}{dr} - \dfrac{2K}{h} = 0$

or $\quad \int dP = -\int \dfrac{2K}{h} . dr$

or $\quad P = -\dfrac{2K}{h} . r + C \qquad$ ...(6)

At $\quad r = R;\ \sigma_r = 0$ (because on this surface there will be no force) and $\sigma_r + P = \sigma_0$; $P = \sigma_0$

$$\sigma_0 = -\frac{2K}{h} . R + C$$

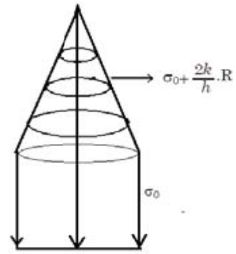
or $\quad C = \sigma_0 + \dfrac{2K}{h} R$

From (6) $\quad P = -\dfrac{2K}{h} . r + \sigma_0 + \dfrac{2K}{h} R$

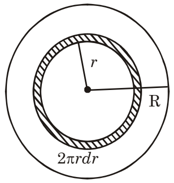
or $\quad P = \sigma_0 + \dfrac{2K}{h} . (R - r) \qquad$ ...(7) Pressure Distribution linear

At $\quad r = 0;\ P_{max} = \sigma_0 + \dfrac{2K}{h} . R$

$\quad r = R;\ P_{min} = \sigma_0$



For finding force:

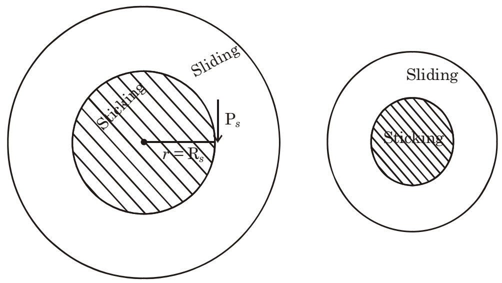


$dF = P . 2\pi r\, dr$

or $\quad F = \int P . 2\pi r\, dr$

or $\quad F = \int_0^R \left[\sigma_0 + \dfrac{2K}{h} . (R - r) \right] 2\pi r\, dr$

Condition 3:
When there is sticking and sliding both frictions occur



For sliding region pressure distribution is same as we derived in previous condition same boundary condition same differential equation.

$$P = \sigma_0 \,.\, e^{\frac{2\mu}{h}(R-r)}$$

For sticking region: Using equation (6).

$$P = -\frac{2K}{h}.r + C$$

Boundary condition at $r = R$; $\quad P = P_s$

or

$$P_s = -\frac{2K}{h}.R_s + C$$

$$C = P_s + \frac{2K}{h}.R_s$$

or

Putting in equation (6)

$$P = -\frac{2K}{h}(r) + P_s + \frac{2K}{h}R_s$$

or

$$P = P_s + \frac{2K}{h}.(R_s - r) \qquad ...(8)$$

$$F_{Total} = F_{sticking} + F_{sliding}$$

$$F_{total} = \int_0^{R_s} P_{sticking} \cdot 2\pi r\,dr + \int_{R_s}^{R} P_{sliding} \cdot 2\pi r\,dr$$

$$F_{total} = \int_0^{R_s}\left[P_s + \frac{2K}{h}(R_s - r)\right]\cdot 2\pi r\,dr + \int_{R_s}^{R} \sigma_0 \,.\, e^{\frac{2\mu}{h}(R-r)}.\,2\pi r\,dr$$

To find P_s and R_s

$$\tau_r = \mu P_s = K$$

$$P_s = \frac{K}{\mu} \qquad ......(9)$$

or

At $\quad r = R_s$; $\quad P = P_s$

$$P_s = \sigma_0\, e^{\frac{2\mu}{h}(R-R_s)}$$

or

$$\frac{K}{\mu} = \sigma_0\, e^{\frac{2\mu}{h}(R-R_s)}$$

$$\ln\left(\frac{K}{\mu\,\sigma_0}\right) = \frac{2\mu}{h}(R - R_s)$$

$$R_s = R - \frac{h}{2\mu}\ln\left(\frac{K}{\mu\,\sigma_0}\right)$$

or

According to Tresca's theory

$$K = \frac{\sigma_0}{2} \qquad \text{or} \qquad \frac{K}{\sigma_0} = \frac{1}{2}$$

$$R_s = R - \frac{h}{2\,\mu}\ln\left(\frac{1}{2\mu}\right) \qquad ...(10)$$

According to Von-Miscs Theory

$$K = \frac{\sigma_0}{\sqrt{3}} \qquad or \quad \frac{K}{\sigma_0} = \frac{1}{\sqrt{3}}$$

$$R_s = R - \frac{h}{2\,\mu}\ln\left(\frac{1}{\sqrt{3}\,\mu}\right) \qquad ...(11)$$

IES – 2006 – Conventional

A certain disc of lead of radius 150 mm and thickness 50 mm is reduced to a thickness of 25 mm by open die forging. If the co-efficient of friction between the job and die is 0.25, determine the maximum forging force. The average shear yield stress of lead can be taken as 4 N/mm² [10 – Marks]

Solution: $R_1 = 150$ mm, $h_1 = 50$ mm, R = ?, $h = 25$ mm, $\mu = 0.25$

$$\pi R_1^2 h_1 = \pi R^2 h$$

R = 212.1 mm

$\tau_y = 4$ N/mm² (Shear yield stress) = K

By Tresca Theory;

$$R_s = 212.1 - \frac{25}{2\times 0.25}\ln\left(\frac{1}{2\times 0.25}\right) = 177.4 \text{ mm}$$

$$\begin{bmatrix} 0\,\text{mm to } 177.4\,\text{mm} & \rightarrow \text{sticking} \\ 177.4\,\text{mm to } 212.1\text{mm} & \rightarrow \text{sliding} \end{bmatrix}$$

$$P_s = \frac{K}{\mu} = \frac{4}{0.25} = 16\,N/mm^2$$

$$\sigma_0 = 2K = 2\times 4 = 8\,N/mm^2$$

$$F_{total} = \int_0^{177.4}\left\{16 + \left(\frac{2\times 4}{25}\right)(177.4 - r)\right\}.\,2\pi r\,dr + \int_{177.4}^{212.1}(8)\times e^{\left\{\left(\frac{2\times 0.25}{25}\right)(212.1-r)\right\}}.\,2\pi r\,dr$$

$= 3.93\,MN$ (Tresca's Theory)

Von Miscs Theory;

$$R_s = 212.1 - \frac{25}{2\times 0.25}\ln\left(\frac{1}{\sqrt{3}\times 0.25}\right) = 170.25 \text{ mm}$$

$$\begin{bmatrix} 0\,\text{mm to } 170.25\,\text{mm} & \rightarrow \text{sticking} \\ 170.25\,\text{mm to } 212.1\text{mm} & \rightarrow \text{sliding} \end{bmatrix}$$

$$P_s = \frac{K}{\mu} = \frac{4}{0.25} = 16\,N/mm^2$$

$$\sigma_0 = K\sqrt{3} = 4\sqrt{3}\,N/mm^2$$

$$F_{total} = \int_0^{R_s}\left\{P_s + \frac{2K}{h}(R_s - r)\right\}\cdot 2\pi r\,dr + \int_{R_s}^{R}\sigma_0\, e^{\frac{2\mu}{h}(R-r)}\cdot 2\pi r\,dr$$

$$F_{total} = \int_0^{170.25}\left\{16 + \frac{2\times 4}{25}(170.25 - r)\right\}\cdot 2\pi r\,dr + \int_{170.25}^{212.1} 4\sqrt{3}.\, e^{\frac{2\times 0.25}{25}(212.1-r)}\cdot 2\pi r\,dr$$

$= 3.6\,MN$ (Von Misces)

Practice Problem -1

A strip of metal with initial dimensions 24 mm x 24 mm x 150 mm is forged between two flat dies to a final size of 6 mm x 96 mm x 150 mm. If the coefficient of friction is 0.05, determine the maximum forging force. Take the average yield strength in tension is 7 N/mm²

Answer:

Given: 2L = 96 mm; L = 48 mm; h = 6 mm; B = 150 mm; $\mu = 0.05$

$$x_s = L - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) \qquad K = 4.04\ N/mm^2$$

$$x_s = -90.155\,mm$$

Since x_s came negative so there will be no sticking only sliding will take place.

$$F = 4\ KB\int_0^L e^{\frac{2\mu}{h}(L-x)}dx$$

$$= 4\times 4.04\times 150\int_0^{48} e^{\left\{\left(\frac{2\times 0.05}{6}\right)(48-x)\right\}}dx = 177.98\ \text{kN}$$

Practice Problem -2

A circular disc of 200 mm in diameter and 100 mm in height is compressed between two flat dies to a height of 50 mm. Coefficient of friction is 0.1 and average yield strength in compression is 230 MPa. Determine the maximum die pressure.

Answer:

$d_1 = 200\,mm; h_1 = 100\,mm; h = 50\,mm; \mu = 0.1; \sigma_Y = 230\,MPa = \sigma_O$

$\because$ Volume before forging = Volume after forging

$$\frac{\pi}{4}d_1^2h_1 = \pi R^2 h \ \ or\ \frac{\pi}{4}\times 200^2\times 100 = \pi R^2\times 50 \Rightarrow R = 141.421\,mm$$

According to Von-Mises

$$R_s = R - \frac{h}{2\mu}\ln\left(\frac{1}{\sqrt{3}\mu}\right) = 141.21 - \frac{50}{2\times 0.1}\ln\left(\frac{1}{\sqrt{3}\times 0.1}\right) = -297.1\,mm$$

According to Tresca

$$R_s = R - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right) = 141.21 - \frac{50}{2\times 0.1}\ln\left(\frac{1}{\sqrt{3}\times 0.1}\right) = -261.1\,mm$$

$\because R_s$ came out to be negative so only sliding friction takes place.

The formula for pressure we get after the slab method of analysis of forging;

$$P = \sigma_o e^{\frac{2\mu}{h}(R-r)}$$

$at\ r = 0; P = P_{max}$

$$P_{max} = 230\times e^{\frac{2\times 0.1}{50}(141.21)} = 404.94\,MPa$$

Practice Problem -3

A cylindrical specimen 150 mm in diameter and 100 mm in height is upsetted by open die forging to a height of 50 mm. Coefficient of friction is 0.2 and flow curve equation is $\sigma_f = 1030\varepsilon^{0.17}$ MPa . Calculate the maximum forging force.

Answer:

$d_1 = 150\,mm; h_1 = 100\,mm; h = 50\,mm; \mu = 0.2;$

$\because$ Volume before forging = Volume after forging

$$\frac{\pi}{4}d_1^2h_1 = \pi R^2 h \ \ or\ \frac{\pi}{4}\times 150^2\times 100 = \pi R^2\times 50 \Rightarrow R = 106.66\,mm$$

$$\text{True strain } (\varepsilon) = \ln\frac{h}{h_1} = \ln\frac{50}{100} = -0.693$$

$$Flow\,stress\,(\sigma_o) = \sigma_f = 1030\varepsilon^{0.17} = 1030\times 0.693^{0.17} = 967.74\,MPa$$

By Tresca Theory;

$$R_s = 106.66 - \frac{50}{2\times 0.2}\ln\left(\frac{1}{2\times 0.2}\right) = -7.87mm$$

Von Miscs Theory;

Practice Problem -4

A circular disc of 200 mm in diameter and 70 mm in height is forged to 40 mm in height. Coefficient of friction is 0.05. The flow curve equation of the material is given by $\sigma_f = 200(0.01+\varepsilon)^{0.41}$ MPa . Determine maximum forging load, mean die pressure and maximum pressure.

Answer:

$d_1 = 200\,mm; h_1 = 70\,mm; h = 40\,mm; \mu = 0.05; \sigma_f = 200(0.01+\varepsilon)^{0.41}$

$\because$ Volume before forging = Volume after forging

$$\frac{\pi}{4}d_1^2h_1 = \pi R^2 h \ \ or\ \frac{\pi}{4}\times 200^2\times 70 = \pi R^2\times 40 \Rightarrow R = 132.28\,mm$$

$$\text{True strain } (\varepsilon) = \ln\frac{h}{h_1} = \ln\frac{40}{70} = -0.5596$$

$$\sigma_f = 200(0.01+\varepsilon)^{0.41}$$

$$\sigma_f = 200(0.01+0.5596)^{0.41} = 158.78 = \sigma_o$$

Now use Tresca's theory

Von-Mises Theory

Practice Problem -5 {GATE-2010 (PI)}

During open die forging process using two flat and parallel dies, a solid circular steel disc of initial radius (R_{IN}) 200 mm and initial height (H_{IN}) 50 mm attains a height (H_{FN}) of 30 mm and radius of R_{FN}. Along the die-disc interfaces.

i. the coefficient of friction (μ) is: $\mu = 0.35\left(1 + e^{-\frac{R_{IN}}{R_{FN}}}\right)$

ii. in the region $R_{ss} \le r \le R_{FN}$, sliding friction prevails, and

$p = \sqrt{3}Ke^{\frac{2\mu}{H_{FN}}(R_{FN}-r)}$ and $\tau = \mu p$,

where p and τ are the normal and shear stresses, respectively; K is the shear yield strength of steel and r is the radial distance of any point

iii. In the region $0 \le r \le R_{SS}$, sticking condition prevails

The value of R_{SS} (in mm), where sticking condition changes to sliding friction, is

(a) 241.76 (b) 254.55 (c) 265.45 (d) 278.20

Answer:

$$\pi R_{IN}^2 H_{IN} = \pi R_{FN}^2 H_{FN}$$

$$or \quad 200^2 \times 50 = R_{FN}^2 \times 30 \Rightarrow R_{FN} = 258.2\,mm$$

$$and \quad \mu = 0.35\left(1 + e^{-\frac{200}{258.2}}\right) = 0.51$$

Now at R_{ss}

Shear stress in sticking K = shear stress in sliding (μP_{ss})

$$or\ K = \mu\sqrt{3}Ke^{\frac{2\mu}{H_{FN}}(R_{FN}-R_{ss})}$$

$$or \ln\left(\frac{1}{\sqrt{3}\mu}\right) = \frac{2\mu}{H_{FN}}(R_{FN} - R_{ss})$$

$$or \frac{H_{FN}}{2\mu}\ln\left(\frac{1}{\sqrt{3}\mu}\right) = R_{FN} - R_{ss}$$

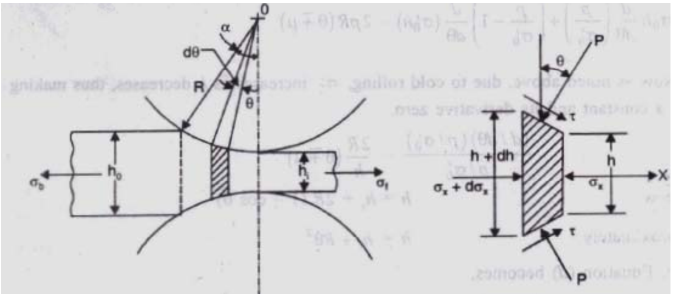
$$or\ R_{ss} = R_{FN} - \frac{H_{FN}}{2\mu}\ln\left(\frac{1}{\sqrt{3}\mu}\right) = 258.2 - \frac{30}{2\times 0.51}\ln\left(\frac{1}{\sqrt{3}\times 0.51}\right) = 254.55\,mm$$

IFS-2012

Discuss Tresca and Von Mises yield criterion for metal forming operations. Also derive tensile and shear yield stress relationships for their approaches. Which of this criterion is more realistic? Why? [10 Marks]

Answer: Refer forging analysis

Analysis of Rolling



Considering the thickness of the element perpendicular to the plane of paper to be unity, We get equilibrium equation in x-direction as, $-\sigma_x h + (\sigma_x + d\sigma_x)(h + dh) - 2pR\,d\theta\,\sin\theta + 2\tau_x R\,d\theta\,\cos\theta = 0$

For sliding friction, $\tau_x = \mu p$ Simplifying and neglecting second order terms, $\sin\theta \cong \theta$ and $\cos\theta = 1$, we get

$$\frac{d(\sigma_x h)}{d\theta} = 2pR(\theta \mp \mu)$$

$$p - \sigma_x = \frac{2}{\sqrt{3}}\sigma_0 = \sigma_0'$$

$$\frac{d}{d\theta}\left[h\left(p - \sigma_0'\right)\right] = 2pR(\theta \mp \mu)$$

$$\frac{d}{d\theta}\left[\sigma_0' h\left(\frac{p}{\sigma_0'} - 1\right)\right] = 2pR(\theta \mp \mu)$$

$$\sigma_0' h \frac{d}{d\theta}\left(\frac{p}{\sigma_0'}\right) + \left(\frac{p}{\sigma_0'} - 1\right)\frac{d}{d\theta}\left(\sigma_0' h\right) = 2pR(\theta \mp \mu)$$

Due to cold rolling, σ_0' increases as h decreases, thus $\sigma_0' h$ nearly a constant and itsderivative zero.

$$\frac{\frac{d}{d\theta}\left(p/\sigma_0'\right)}{p/\sigma_0'} = \frac{2R}{h}(\theta \mp \mu)$$

$$h = h_f + 2R(1 - \cos\theta) \approx h_f + R\theta^2$$

$$\frac{d\left(p/\sigma_0'\right)}{\left(p/\sigma_0'\right)} = \frac{2R}{h_f + R\theta^2}(\theta \mp \mu)\,d\theta$$

Integrating both side

$$\ln\left(p/\sigma_0'\right) = \int \frac{2R\theta\,d\theta}{h_f + R\theta^2} \mp \int \frac{2R\mu}{h_f + R\theta^2}\,d\theta = I \mp II \text{ (say)}$$

$$I = \int \frac{2R\theta d\theta}{h_f + R\theta^2} = \int \frac{2R\theta d\theta}{h} = \int \frac{2\theta d\theta}{h/R} = \ln\left(\frac{h}{R}\right)$$

Now $h/R = \frac{h_f}{R} + \theta^2$

or $\frac{d}{d\theta}\left(\frac{h}{R}\right) = 2\theta$

$$II = \int \frac{2R\mu}{h_f + R\theta^2}\,d\theta$$

$$= \int \frac{2\mu}{h_f/R + \theta^2}\,d\theta$$

$$= 2\mu\sqrt{\frac{R}{h_f}}.\tan^{-1}\left(\sqrt{\frac{R}{h_f}}.\theta\right)$$

$$\therefore \quad \ln\left(p/\sigma_0'\right) = \ln\left(\frac{h}{R}\right) \mp 2\mu\sqrt{\frac{R}{h_f}}.\tan^{-1}\left(\sqrt{\frac{R}{h_f}}.\theta\right) + \ln C$$

$$\therefore \quad p = C\sigma_0'\left(\frac{h}{R}\right)e^{\mp\mu H}$$

where $H = 2\sqrt{\frac{R}{h_f}}.\tan^{-1}\left(\sqrt{\frac{R}{h_f}}.\theta\right)$

Now at entry, $\theta = \alpha$

Hence $H = H_0$ with θ replaced by ∝ in above equation

At exit $\theta = 0$

Therefor $p = \sigma_0'$

In the entry zone, $p = C.\sigma_0'\left(\frac{h_o}{R}\right)e^{-\mu H_o}$

and $C = \frac{R}{h_o}.e^{\mu H_o}$

$$p = \sigma_0' \frac{h}{h_0}.\ e^{\mu(H_0 - H)}$$

In the exit zone

$$p = \sigma_0'\left(\frac{h}{h_f}\right).e^{\mu H}$$

At the neutral point above equations will give same results

$$\frac{h_n}{h_0}.\ e^{\mu(H_0 - H_n)} = \frac{h_n}{h_f}.\ e^{\mu H_n}$$

or $\frac{h_o}{h_f} = e^{\mu(H_0 - 2H_n)}$

or $H_n = \frac{1}{2}\left[H_0 - \frac{1}{\mu}\ln\left(\frac{h_0}{h_f}\right)\right]$

From $H = 2\sqrt{\frac{R}{h_f}}.\tan^{-1}\left(\sqrt{\frac{R}{h_f}}.\theta\right)$

$$\therefore \theta_n = \sqrt{\frac{h_f}{R}}.\tan\left(\sqrt{\frac{h_f}{R}}.\frac{H_n}{2}\right)$$

and $h_n = h_f + 2R(1 - \cos\theta_n)$

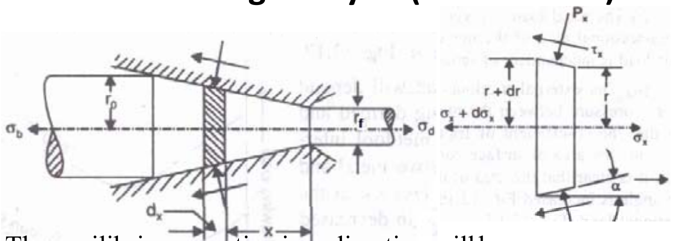
If back tension σ_b is there at Entry,

$$p = \left(\sigma_o' - \sigma_b\right)\frac{h}{h_0}.\ e^{\mu(H_0 - H)}$$

If front tension σ_f is there at Exit,

$$p = \left(\sigma_o' - \sigma_f\right)\frac{h}{h_f}.\ e^{\mu H}$$

Wire Drawing Analysis (Home Work)



The equilibrium equation in x-direction will be

$$(\sigma_x + d\sigma_x)\pi(r+dr)^2 - \sigma_x \pi r^2 + \tau_x \cos\alpha\left(2\pi r\frac{dx}{\cos\alpha}\right) + P_x \sin\alpha\left(2\pi r\frac{dx}{\cos\alpha}\right) = 0$$

or $\sigma_x 2rdr + d\sigma_x r^2 + 2r\tau_x dx + P_x 2rdx\tan\alpha = 0$

Dividing by r^2dr and taking $dx/dr = \cot\alpha$ we get

$$\frac{d\sigma_x}{dr} + \frac{2}{r}(\sigma_x + P_x) + \frac{2\tau_x}{r}\cot\alpha = 0$$

Vertical component of $P_x \cong P_x$ due to small half die angles and that of τ_x can be neglected.

Thefore, two principal stresses are σ_x and $-P_x$

Both Tresca's and Von-Mises criteria will give

$$\sigma_x + P_x = \sigma_o$$

and $\tau_x = \mu P_x = \mu(\sigma_o - \sigma_x)$

$$\frac{d\sigma_x}{dr} + \frac{2\sigma_o}{r} + \frac{2\mu(\sigma_o - \sigma_x)}{r}\cot\alpha = 0$$

Let $\mu\cot\alpha = B$

$$\frac{d\sigma_x}{dr} = \frac{2}{r}\left[B\sigma_x - (1+B)\sigma_o\right]$$

$$or \quad \frac{d\sigma_x}{\left[B\sigma_x - (1+B)\sigma_o\right]} = \frac{2}{r}dr$$

Integrating both side

$$\ln\left[B\sigma_x - (1+B)\sigma_o\right]\times\frac{1}{B} = 2\ln(rC)$$

{C is integration cont.}

$$or \quad B\sigma_x - (1+B)\sigma_o = (rC)^{2B}$$

$B.C^s$ at $r = r_o, \sigma_x = \sigma_b$

$$\therefore C = \frac{\left[B\sigma_b - (1+B)\sigma_o\right]^{\frac{1}{2B}}}{r_o}$$

$$or\ \sigma_x = \frac{\sigma_o(1+B)}{B}\left[1 - \left(\frac{r}{r_o}\right)^{2B}\right] + \left(\frac{r}{r_o}\right)^{2B}.\sigma_b$$

$$\therefore Drawing\ stress\,(\sigma_d) = \frac{\sigma_o(1+B)}{B}\left[1 - \left(\frac{r_f}{r_o}\right)^{2B}\right] + \left(\frac{r_f}{r_o}\right)^{2B}.\sigma_b$$

Extrusion Analysis (Home Work)

For a round bar both wire drawing and extrusion will give same equation except $B.C^s$

$$\therefore\ B\sigma_x - (1+B)\sigma_o = (rC)^{2B}$$

$B.C^s$ at $r = r_f, \sigma_x = 0$ (at exit stress is zero)

$$\therefore C = \frac{\left[-(1+B)\sigma_o\right]^{\frac{1}{2B}}}{r_f}$$

$$or\ \sigma_x = \frac{\sigma_o(1+B)}{B}\left[1 - \left(\frac{r}{r_f}\right)^{2B}\right]$$

at $r = r_o$

$$\sigma_{xo} = \frac{\sigma_o(1+B)}{B}\left[1 - \left(\frac{r_o}{r_f}\right)^{2B}\right]$$

Extrusion ratio, $R = \frac{A_o}{A_f} = \left(\frac{r_o}{r_f}\right)^2$ for round bar

$= \left(\frac{h_o}{h_f}\right)$ for flat stock

$$\sigma_{xo} = \frac{\sigma_o(1+B)}{B}\left[1 - R^{2B}\right]$$

If effect of container friction is considered

p_f = ram pressure required by container friction

τ_i = uniform interface shear stress between billet and container wall

$p_f.\pi r_0^2 = 2\pi r_0 \tau_i L$ or $p_f = \frac{2\tau_i L}{r_o}$

$\therefore$ Total Extrusion Pressure(P_t) $= \sigma_{xo} + p_f$

and Extrusion Load $= p_t.\pi r_0^2$

GATE -2019: Mechanical

Following Topics are very important for GATE Examination

Grade-A Subjects ....more than 10 revisions are required

- *Mathematics* (2011 By IIT Madras-13%)
- *Production* (2011 By IIT Madras-12%)
- *SOM* (2011 By IIT Madras-12%)
- *TOM* (2011 By IIT Madras-7%)
- *Thermodynamics* (2011 By IIT Madras-7%)
- *Power plant* (2011 By IIT Madras-7%)
- *Fluid Mechanics & Machines* (2011 By IIT Madras-5%)

Grade-B Subjects ....more than 5 revisions are required

- *Industrial Engineering* (2011 By IIT Madras-5%)
- *Heat Transfer* (2011 By IIT Madras-5%)
- *Engineering Mechanics* (2011 By IIT Madras-5%)

Grade-C Subjects ....less than 5 revisions are required

- *Design* (2011 By IIT Madras-2%)
- *RAC* (2011 By IIT Madras-1%)

Grade-D Subjects ....1 or 2 revisions are sufficient

- *IC Engine* (2011 By IIT Madras-2%)
- *Engineering Materials* (2011 By IIT Madras-1%)

Detailed Topics

1. Mathematics

a) Probability and Statistics
b) Eigen Values and Eigen Vectors
c) Differential Equations

d) Transform Theory
e) Numerical Methods
f) Calculus, Gradient, Multiple Integrals
g) Complex Variables
h) Matrix Algebra
i) Fourier Series
j) Partial Derivatives

2. Production

a) Theory of metal cutting, forces, tool life
b) Rolling calculations
c) Wire drawing and Extrusion Calculations
d) Sheet metal operations, clearance, force, power, shear calculations
e) Lathe, drilling, milling, shaping cutting time calculations, all numericals
f) Grinding and finishing
g) ECM MRR, feed calculations, EDM theory, comparison of all NTMM
h) NC/CNC Machine, BLU calculations, upto M & G code
i) Limit, tolerance, fit
j) Jig & Fixture, 3-2-1 principle
k) **Welding:** V-I Characteristics calculations, Resistance welding calculations, Special welding theory
l) **Casting:** allowances, Riser Design, Sprue Design, Pouring time calculations, Special Castings, Casting Defects.

3. SOM

a) Principal Stress and Principal Strain, Mohr Circle(VIMP)
b) Stress and Strain (VIMP)
c) Bending Moment and Shear Force Diagram (VIMP)
d) Deflection of Beam
e) Torsion
f) Theories of Column (Euler method, end conditions)
g) Strain Energy Method (Castigliano's theory)
h) Theories of failure
i) Thin cylinder
j) Riveted and Welded Joint
k) Spring

4. TOM

a) Mechanism (VIMP)
b) Linear Vibration Analysis of Mechanical Systems (VIMP)
c) Gear train (VIMP)
d) Flywheel (Coefficient of Fluctuation of speed, Coefficient of Fluctuation of energy), mass calculation,
e) Critical Speed of Shafts
f) Gyroscope

5. Thermodynamics

a) Basic Concepts
b) Application of First law
c) Entropy, Availability
d) Pure Substance (VIMP)
e) Gases and Gas mixture

6. Power plant

a) Steam Cycle (VIMP)
b) Gas Cycle
c) Compressor

7. Fluid Mechanics & Fluid Machines

a) Properties of fluid
b) Pressure measurement, manometers
c) Fluid kinematics (VIMP)
d) Bernoulli's Equation (Fluid Dynamics)
e) Venturimeter
f) Flow (Laminar and Turbulent)
g) Boundary Layer, Thermal Boundary Layer
h) Compressible Flow
i) Hydraulic Turbine
j) Centrifugal Pump

8. Industrial Engineering

a) EOQ Models (VIMP)
b) PERT & CPM (VIMP)
c) Queuing Model (VIMP)
d) Forecasting (VIMP)
e) LPP
f) Work Study & Work Measurement (standard time calculations, theriblings symbol)
g) Break even Analysis
h) The Scheduling Problem and Johnson's Rule
i) Assembly line balancing

9. Heat Transfer

a) Conduction
b) Critical Thickness of Insulation
c) Unsteady Conduction (Lumped Parameter Analysis)
d) Radiation (The Stefan-Boltzmann Law, Shape Factor Algebra, Heat Exchange between Non-black Bodies)
e) Heat Exchangers (LMTD, NTU)

10. Engineering Mechanics

a) Equilibrium
b) Truss
c) Friction

11. Design

a) Fluctuating Load Consideration for Design
b) Rolling Contact Bearings, Load-life Relationship
c) Sliding contact bearing, Modes of Lubrication, Sommerfeld Number
d) Clutch , Brake

12. RAC

a) Heat engine, heat pump, refrigerator (VIMP)
b) Psychrometry (VIMP)
c) Vapour Compression Systems

13. IC Engine

a) Gas Power Cycles (All) (VIMP)
b) IC Engine Performances
c) Octane number, cetane number

14. Engineering materials

a) Crystal structure & crystal defects
b) Iron-carbon Equilibrium diagram, TTT diagram,
c) Heat treatment

General Guidelines

- Please follow the step by step procedure given below for preparing GATE where only objective type questions are asked.
- I found that in all competitive examinations similar type of questions are asked. They are similar but not the same. The questions are not repeated but the theory (Funda) which is needed to solve the question remains same. So you don't need to remember the questions and answers but you must remember the funda behind it.
- GATE papers are set by Professors of IITs and they check student's fundamentals of the subject. So we must be prepared with fundamentals. That's why funda is repeated.
- You know that in the engineering books are not made for objective type questions. The theory involves rigorous derivations, enormous calculations etc and our University examinations are also conventional type.
- We have to prepare for Objective Questions.

For regular eye on your progress

- Paste the topic list in front of study table, tick mark the topics completed by you (class note + all questions from question set) on daily basis.
- One tick when topic is completed once, then second tick after the second revision, and so on.
- Topic list should contain as many tick marks as many times revision for a particular topic is completed.
- Once one subject gets completed it has to be revised frequently (once in a month or so), so that formulae can be remembered on the long run.

For Students' who are attending coaching

- Attend all classes.
- Meticulously read class notes
- From the question set solve all previous year asked questions which are given in topic wise sequence.
- It is recommended to solve my question set on your own and then cross check with my explanations.
- Mathematics (Class note + My Question set)
- Manufacturing Science (Class note + My Question set GATE,IES,IAS)
- SOM (Class note + My Question set GATE,IES,IAS)

- TOM (Class note + Question set GATE,IES,IAS)
- Industrial Engineering (Class note + Question set GATE,IES,IAS)
- Engineering Mechanics (Book: D P Sharma or Bansal or Khurmi)
- Thermodynamics {Class note + P K Nag Unsolved all (My solutions available)}
- Fluid Mechanics & Machines (Class note + Only 20 Years GATE Questions)
- Heat Transfer (Class note + Only 20 Years GATE Questions)
- Design (Class note + Only 20 Years GATE Questions)
- RAC (Class note + Only 20 Years GATE Questions)
- Power plant (Class note + Only 20 Years GATE Questions)
- IC Engine (Class note + Only 20 Years GATE Questions)
- Engineering Materials (Class note + Only 20 Years GATE Questions)

For self preparing students

- Meticulously read book only of the topics mentioned in topic list.
- Practice all solved examples from the books of respective subject as listed below of ONLY the topics mentioned in the topic list
- It is recommended to solve my question set on your own and cross check with my explanations.
- Mathematics (Grewal or Dash + My Question set)
- Manufacturing Science { Book P.C Sharma (Vol 1& 2) + My Question set GATE,IES,IAS }
- SOM (Book Sadhu Singh or B.C Punmia or only My Book + My Question set GATE,IES,IAS)
- TOM (Book Ghosh Mallick + My Question set GATE,IES,IAS)
- Industrial Engineering (Ravi Shankar or Kanti Swarup or my book + My Question set GATE,IES,IAS)
- Engineering Mechanics (Book: D P Sharma or Bansal)
- Thermodynamics {Book Rajput + P K Nag Unsolved all (My solutions available)}
- Fluid Mechanics & Machines (Book Bansal or Rajput or my book + Only 20 Years GATE Questions, My set)
- Heat Transfer (Book Rajput or Domkundwar + Only 20 Years GATE Questions, My set)
- Design (Book Bhandari or Khurmi + Only 20 Years GATE Questions, My set)
- RAC (Book Rajput or CP Arora+ Only 20 Years GATE Questions, My set)
- Power plant (Book PK Nag + Only 20 Years GATE Questions, My set)
- IC Engine (Book V Ganeshan + Only 20 Years GATE Questions, My set)
- Engineering Materials (NPTEL IISc material from net + Only 20 Years GATE Questions, My set)